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The Key To The Treasury

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ENGINE FOUNDATIONS

Cement, the Universal Material. Weight to Use. Form to Give It. Footings, Templet Forms and Grouting

IN PROVIDING THE FOUNDATIONS for steam engines and turbines, 3 objects must be kept in view: First, to support the weight of the machine; second, to hold the bearings in alinement; and third, to prevent vibration. Usually, if the foundations are sufficiently large to give a bearing for all parts of the frame, and are sufficiently heavy to take care of the vibration, the other points will be taken care of effectively.

At the present time concrete is the almost universal material for foundations. Formerly brick and stone

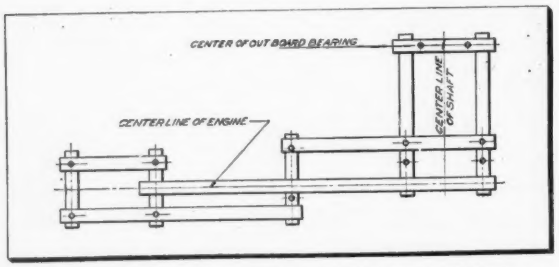


FIG.1. TEMPLET FOR ENGINE FOUNDATION BOLTS

were used to a considerable extent, but at the present time stone is practically discarded and brick is used in but few instances.

To Make Good Concrete

FOR this work, the concrete is made in proportions of one of cement, 2 of sand, and 4 of crushed stone. The sand must be clean, so that it will not soil the hands in handling, and containing no particles over ¼ in. in diameter. If earthy matter is found in the sand, it must be washed out or the concrete will not be firm. Only the best Portland cement should be used, and must not have been exposed to dampness, so that it is caked.

Stone should be not over 1¼ in. in the largest dimension, and works best if crushed so as to present irregular surfaces. Cobble stones and gravel are sometimes used, but should always be washed carefully and well wetted before mixing.

For the proportions given, a cubic yard of concrete will need 5.84 bags of cement; 0.41 cu. yd. of sand, weighing 1100 lb.; 0.82 cu. yd. of stone, weighing 2050 lb., and 26 gal. of water. This will give a concrete weighing, when reasonably well seasoned, 150 lb. per cu. ft.

In mixing the concrete, the sand should first be spread in an even layer on a floor of loose planks, then the cement spread evenly on top and mixed thoroughly with the sand. The water should then be poured on, turning over the cement and sand in order to mix the mass to a smooth mortar. The mortar should then be leveled, the stone wet, spread on, and the mass turned over twice to make sure that all stones are covered with mortar. Unless more than one set of men are working, not more than a cubic yard of mortar should be mixed at one time, in order to avoid setting before it reaches the foundation.

When Using Brick

IF brick is used, only the hard-burnt variety should be permitted, and this should be well wetted before laying. Joints should be made close, using as little mortar as possible, and this mortar should be made of one part Portland cement and 2 parts sand. Lime mortar should never be used. For a cubic yard of masonry, 594 brick will be needed, and the resulting foundation will weigh 125 lb. per cubic foot.

In determining the size of foundation, not only the weight of the machine must be considered, but the amount of unbalanced thrust from the reciprocating and rotating parts.

How Large Shall It Be?

BOYER states that for engines, a weight 1½ times that of the machine will be sufficient for ordinary low-pressure, moderate speed practice. This, however, depends on the speed and the amount of the unbalancing, and is usually determined by experience of the engine builders.

To avoid danger of cracking, the depth must be ample, and usually this depth, together with sufficient area to take the foundation bolts, will give all weight that is necessary. For 1-in. bolts, the hole should be at least 10 in. from the edge of the foundation; for 2-in. bolts, 14 in., and for 3-in. bolts, 18 in. In the matter of depth, for small engines 1½ ft. will be sufficient; for low-speed, horizontal engines of 40 hp., 5 ft.; for 200 hp., 9 to 10 ft.; for 600 hp., 11 to 12 ft.; for 1000 hp., 15 ft.; and so on up to 25 ft., which is sufficient depth for the largest vertical engines. For vertical engines, somewhat greater depth is needed than for the horizontal type, as the thrust of the reciprocating parts is carried directly to the foundation.

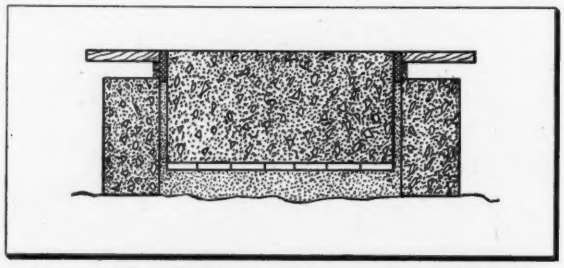


FIG. 3. SAND CUSHION TO PREVENT VIBRATION FROM FOUNDATION TO BUILDING

In determining the bearing surface needed on top of the foundation, concrete may be assumed to carry safely a load of 25 tons per square foot when it is one month old.

Care should be taken in making pipe channels, that no part is left without sufficient support, and in case of suspected weakness, it is best to use reinforcing rods in the angles, or to put in tie rods across the top of the pipe channel.

Area for Footings

IN arranging the distribution of the foundation weight, the center of weight of the machine should come over the center of the foundation, so that the settling will be even if the soil is of uniform character. Where the soil is soft, it is necessary to spread the foundation at the bottom, in order to get sufficient bearing, and in this case a good proportion for the slope or batter is 1 to 1; that is 1 ft. increase in the length and in the breadth of the foundation for each foot depth.

In determining the bearing power of the soil, it should be remembered that the soil has to carry the weight of the foundation as well as that of the engine, and the footings should be figured accordingly. Generally accepted values for the bearing power of soils are: For hard rock, 200 tons per sq. ft.; for soft, crumbling rock, 18 tons; for heavy clay, 4 to 6 tons; for dry clay, 2 to 4 tons; for soft clay, 1 to 2 tons; for a compact sand, 4 to 6 tons; for a clean, dry sand, 2 to 4 tons; for alluvial earth, ½ to 1 ton.

Where the outboard bearing pedestal is carried up separate from the main foundation, to provide for a flywheel pit, a broad footing should be spread under the entire area, of a depth from 16 in. up to 3 ft., depending on the size of the foundation.

In the case of a mud bottom, it is usually necessary to drive piles until there is little give under the impact of the ordinary pile driver, then excavate between the heads of these piles to a depth of 2 ft.; put in a foot of dry sand and fill in on top of this with concrete to the height needed for the footing, but never less than 2 ft. in thickness.

The Templet for Bolts

WHEN putting down the foundation, the first step is to make a templet of boards, on which the center lines for the cylinder and guides and the shaft can be laid out, all bolt holes laid off from these, and small holes bored through the templet, through which to pass plumb lines.

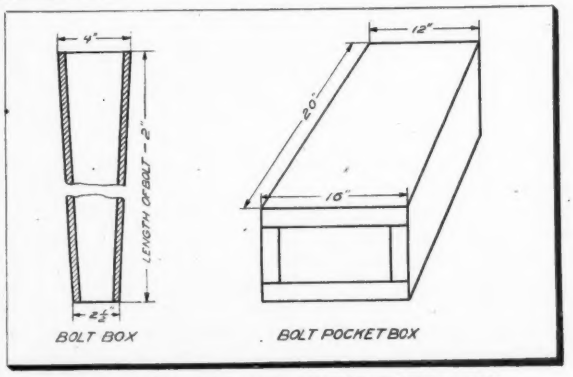


FIG. 2. BOLT BOX AND ANCHOR POCKET BOX

The practice of hanging the foundation bolts on the templet is not to be recommended, as it is likely to pull the templet out of place, and settling of the foundation as it progresses may draw the bolts down too far.

The templet should be carefully placed in position by measurement from some datum line, or by the use of a transit, and supported sufficiently so that it will not be displaced while putting in the foundation. Plumb lines should then be dropped through the holes, which indicate the centers of foundation bolts, and around these should be placed the foundation bolt boxes.

Building Concrete Foundations

IF concrete is to be used, forms must be made up of the shape of the desired foundation, using lumber at least 1¾ in. thick, dressed on one side and the edges, and braced every 2½ ft. outside to take the pressure of the ramming, and every foot inside to hold the planks in position, the inside braces being, of course, removed as the concrete is placed.

Boxes for the bolt holes may well be made as shown in Fig. 2, the flare at the top permitting of movement of the bolts in case the holes in the engine bed are not quite according to the blue print. Some installing men prefer to use pieces of oil boiler tube, a little larger

Cylinder	Speed r. p. m.	Main Foundation			Outboard	
		Length	Breadth	Depth	Length	Breadth
9x18		11′-0″	3′-0″	5′-0″	5′-10″	24″
12x30	170	20′-9″	4′-10″	6′-1″	9′-2″	27″
16x32	150	22′-7″	4′-10″	6′-1″	9′-2″	27″
18x36	145	24′-2″	5′-6″	7′-9″	10′-6″	27″
24x42	120	27′-8″	7′-0″	9′-3″	12′-4″	3′
30x48	100	32′-7″	9′-0″	12′-7″	15′-8″	4′
36x54	90	37′-3″	10′-0″	14′-0″	16′-0″	5′
40x60	80	39′-11″	11′-6″	15′-6″	17′-0″	5′-6″
44x66	75	42′-4″	11′-6″	15′-6″	17′-0″	6′-0″

FIG. 4. DIMENSIONS FOR FOUNDATIONS FOR SIMPLE CORLISS ENGINE

in diameter than the bolt, and leave this in position in the foundation, thus allowing the bolt some movement at all times, and giving the entire length of the bolt to stretch and act as a spring under any extra severe shock which may come on the engine in operation.

Where the boxes are used, these are to be removed after the foundation is completed and the holes filled with cement when setting the engine bed.

The forms for pockets shown in Fig. 2 are used for making the openings into which the cast-iron washers for the bottom ends of the bolts are placed. Both bolt boxes and pocket forms should be soaked in water for 2 hours before using in the foundation, in order to avoid swelling when the concrete is being laid.

When the forms are all ready and the boxes in place, the concrete should be mixed so that none of it will stand over 20 minutes after mixing before being rammed. It should be placed in layers not over 6 in. in depth, and rammed into place with rammers whose weight is 1 lb. per sq. in. of face, until water and cement appear on the surface of the concrete. Then another 6-in. layer should be put in place and rammed, and so on.

For a small job, the operation should be completed before stopping. In large work, where it is necessary to stop over night, the surface should be roughened and grooved where it is left for the night, and preferably covered with wet rags. In the morning it should be roughened up somewhat, wet down thoroughly, and dusted with dry cement before putting in the next layer. If this is not done, the 2 layers will not unite solid, and a crack in the foundation will develop.

Frequently, in large foundations, stones up to 8 in. diameter may be used for filling, provided they are kept at least a foot from any surface and a foot from each other, and are well wetted before putting in.

In some small foundations slushed concrete is used that is mixed thin so that it will pour into place without ramming, but this requires longer to set and does not make so good a foundation as the rammed concrete. If it is used, care should be taken that it is not so thin, that the stone will be likely to settle to the bottom.

For Laying Brick

IN laying brick foundations, the only care is to make joints carefully, to see that all brick are sound and that the joints are as thin as possible. For filling in, broken brick is often used, slushed in place with a cement mortar similar to a concrete foundation, and this will be satisfactory if the pieces of brick are not too large, and care is taken that the voids are completely filled with mortar. For a brick foundation, capstones of dressed masonry or of concrete should be used for the engine frame to rest upon.

Bolts and Washers

FOR either concrete or brick foundations, at least 2 weeks should be allowed for the cement to set before the frame is put in place and the foundation bolts tightened up.

If the work is large and important, the bolts should have the ends upset, so that the bottoms of the threads are as large in diameter as the body of the bolt. Washers for the bottom ends are made either of heavy boiler plate or of cast iron, and are best made removable—that is, not built into the masonry. The use of a nut on the bottom end of the bolt is always to be preferred, as this permits of bringing the top of the bolt flush with the nut at the upper end, and avoids cutting off the bolts after the engine is in position.

To Avoid Transmitting Vibration

IN cases where the foundation rests on rock, it is frequently necessary to avoid the transmission of vibration to the foundations of buildings or other machinery. In such a case, a sand cushion is usually introduced at the bottom and sides of the foundation, 6 in. of sand being used at the bottom and a layer 2 in. thick around the sides and ends. A retaining wall is first erected, 2 in. larger than the foundation, on all sides. Two-inch planks are then put in on end, and the foundation built inside of this upon a 6-in. bed of sand. After the foundation is set, the planks are removed, and sand is rammed into the space thus left. If bolt pockets are used in this style of foundation, it is necessary to carry the boxes through the retaining wall and into the foundation, and enough of the outer end must be left in place to pass through the sand cushion.

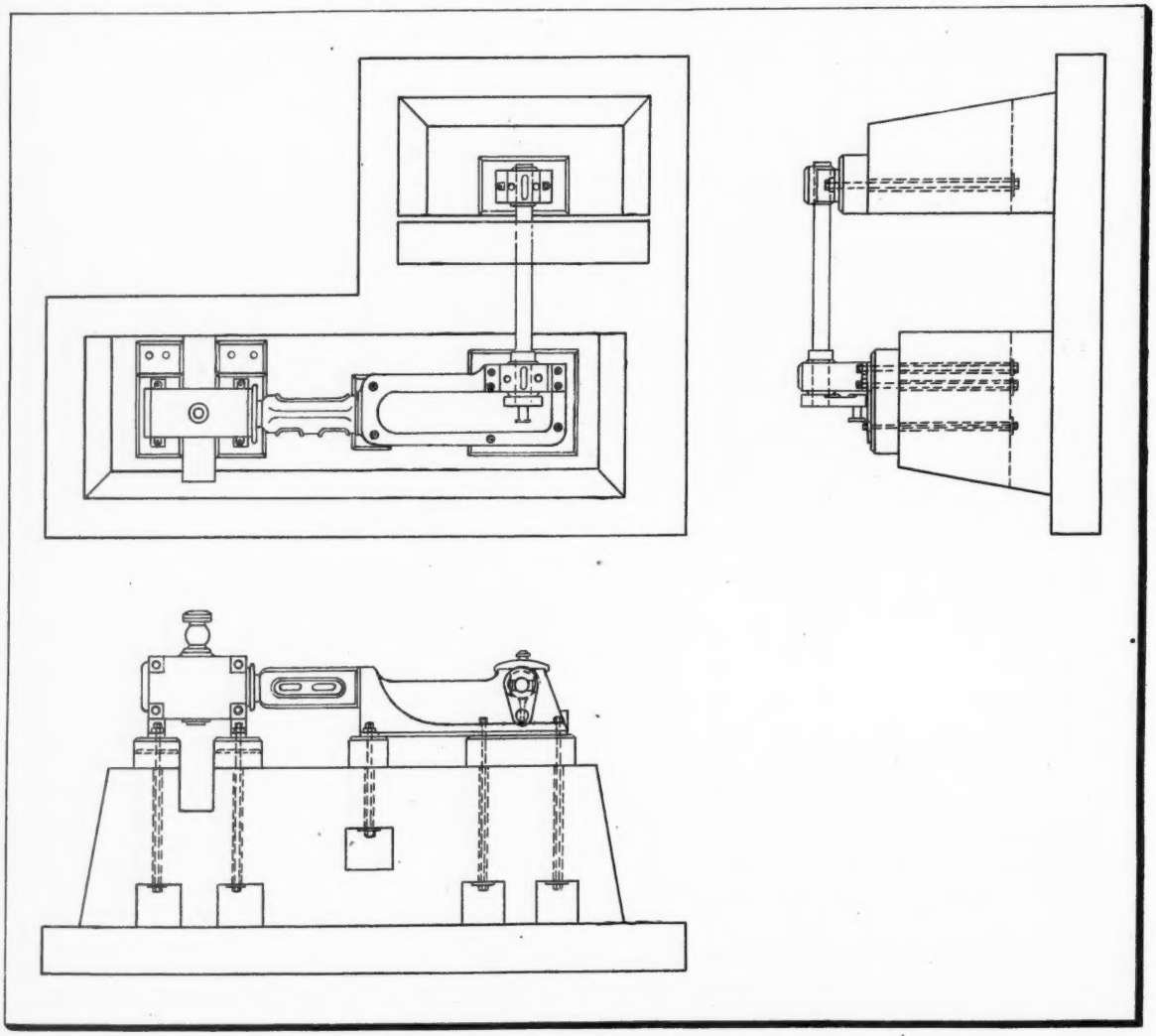


FIG. 5. TYPICAL FORM OF ENGINE FOUNDATION

Another method sometimes used is to separate the top of the foundation from the bottom, putting in rubber washers to take up the vibration of the engine. These go in around the foundation bolts and are made 4 in. in diameter, by 3 in. thick. They may, of course, be placed between the sub-base and the foundation, but this does not give as steady running as when they are placed between 2 pieces of concrete.

For appearance, the outside of the foundation is sometimes slushed over with cement mortar, troweled to a smooth surface, and the top of the foundation should always be so treated in order to give a level bearing for the frame or sub-base.

Bolting Down and Grouting

WITH the engine in place and the bolts in proper position, the frame is leveled up by means of thin iron wedges and iron bearing plates, the level being placed along the lower crosshead guide and across the main bearing. In connection with this, the article on Lining Up of Engines should be read.

When the engine is properly leveled, it is grouted in place with cement, a rust joint, or sulphur, the cement being most commonly used. This is mixed of one part Portland cement and one part sand, to the consistency of thick paint. A wall of sand is built around the base of the engine at some 2 in. from the outer edge, and the grout is poured in under the frame. Care should be taken that all air pockets in the frame are properly vented, so that there may be no backing up of the grout, and all bottom surfaces should be brought to a full bearing at all points.

It is well to use, in this connection, pieces of scrap-iron ⅛ in. thick and some 2 in. wide, and to push the grout under all parts of the frame, so that all air may be worked out and all corners filled. After the grout has stood for some 24 hr., the sand dam may be taken down, the wedges removed and the places where they have been filled with a grout somewhat thicker than that at first used, and carefully rammed into place with the scrap-iron. After another 24 hr., the extra material may be cut away from around the outside of the frame, and after a week the foundation bolts may be tightened down. When thoroughly dry, the grouting and top of the foundation should be given a coat of water-proof paint, to prevent the action of oil.

If a rust joint is used, it should be mixed in the proportions of one bucket of iron chips, one-half bucket of water and a handful of salt. This should be allowed to stand for a while, and then rammed in a little at a time until it gives a hard metallic sound like striking the engine frame with a hammer. To get a backing, oakum may be rammed under the engine frame at the farther edge, but it is better to provide a stop piece so that the rust mixture may be carried clear to the edge of the frame at all points.

If sulphur is used, it is melted and poured in place in much the same way as the cement grout, but it is not nearly as good, as it is brittle under shock and rots under the action of oil.

After the grout is fully set, the leveling of the engine should be carefully tested again and the foundation bolts drawn up tight, watching the levels all the time to see that no springing occurs. When the bolts are up tight, the holes around the bolts may be filled with the grouting material, if desired, but, as previously stated, many prefer to leave these unfilled to provide for spring, and future convenience in repairing.

LINING UP THE ENGINE

IN THE high-speed type of engine, lining up is a simple matter, as the frame and cylinder are machined in such a way that cylinder and guides are held in line by the construction, and the main bearings are machined at right angles to the guides in the factory. The outboard bearing is, therefore, the only part which usually needs attention, and this can be brought into line by clamping the main shaft firmly into the main bearing, and adjusting the outboard so that it lines up with the end of the shaft.

Causes for Out of Line

IT is unsafe to assume that the engine will line up, if the parts are placed together and the bolts screwed up hard.

With a heavy-duty frame having the guide barrel cast on, the casting is made bottom side up, and it may be that the metal on one side of the flange or on one guide, is harder than that on the other, so that the boring bar springs when the tool encounters the hard spot, or gives a little in facing up the flange at the hard spot and cuts in deep on the soft side. A cylinder bolted to such a frame may be out of line considerably.

In many modern engines, bosses are cast on the sides of the guide barrel and are bored off when boring the guides. After the guides and bosses have been bored, a counterbore is frequently made at each end, ⅛ in. larger than the guide bore, and also cutting into the bosses, thus giving 4 lining points at each end of the guide barrel, which are not affected by wear. Cylinders invariably have a counterbore at either end, so that with this construction, lining up is greatly simplified.

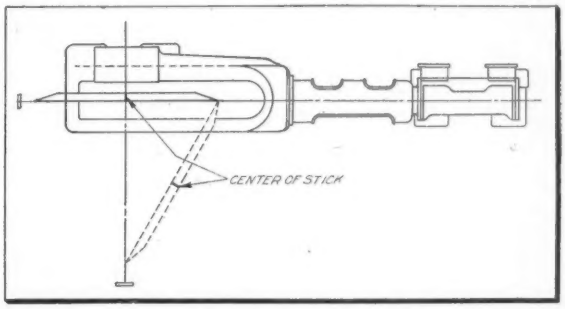


FIG. 2. USING THE CENTER LINES TO SQUARE UP THE SHAFT

Leveling the Frame

IN the case of a new engine, first, make sure that the foundation bolts, or the bolt holes, check up with those in the engine frame. Then place the frame in position, with the bolts in place, and level by means of wedges, lengthwise for the lower guide and crosswise for the main bearing or the surface where the cap fits. The wedges should be placed close to foundation bolts, 2 under the bearing, one on each side at the front end of the guides and the same at the back end of guides, and the frame brought to exact level.

The cylinder may now be attached to the frame, making sure that there are no burs on the finished faces, and that it is level crosswise and lengthwise. Then draw up on the stud bolts equally all around several times, watching the levels all the time until the cylinder seems to be tight in place.

Stretching the Center Line

A LINE should then be stretched through the entire engine and fastened to adjustable targets, either on the frame and cylinder, or, better, at a distance behind the cylinder and in front of the main bearing, using a fine silk or sea grass line, stretched tight enough to take out the sag, and arranged in such a way as to permit of a slight adjustment in any direction.

Secure several small sticks of soft wood about the size of a lead pencil, cut them ½ in. shorter than the radius of the cylinder and guide, and in the end of each stick place a small brad rounded on the point. Then by tramming top and bottom and sidewise, adjust the line so that it is exactly central to the guides. Now test the cylinder to see that it checks up with the line; finding, if it is faulty, the amount by using a thickness gage or paper of known thickness under the tram.

Truing the Frame

IF the cylinder is out of line, and not over 0.012 in. low at the back end, this can usually be taken up by wedging up the rear end of the cylinder, watching to see that the level of the frame and adjustment of the line in the guides has not been affected. If, however, the cylinder is out sidewise, the only remedy is to back off the cylinder far enough so that the end of the frame, or the head, can be filed.

After the filing, it is, of course, necessary to bring all parts of the cylinder into place again, draw up on the stud bolts evenly, being sure that all parts are kept carefully in line and to test for the alinement.

For Bar or Slipper Guides

IF the engine has bar or slipper guides, it is best to set the stretched line to the cylinder first, and if it lines with the crankpin on both centers, to set the guides so that they will line with the axis of the cylinder and be at the right distance from the center line to take the crosshead. This usually involves the use of shims under the guide bars.

After cylinder and guides are properly lined, the main shaft must be squared up to the center line. It is best to have the shaft set so that its center will be in the same plane as the center line of the engine, but, if the shaft is a small amount high or low, it will not materially affect successful operation.

Squaring the Shaft

HAVING brought the shaft level, adjust the outboard end sidewise so that when the crankpin is brought against the stretched line at either center, the distances from the line to the face of the crank, or to the end of the pin, will be the same at both centers.

If it is desired to line up the bearings before the shaft is set into them, this may be done by stretching a line through the center of the main bearing to the outboard bearing, then moving the outboard bearing sidewise until this line is at right angles to the center line through the cylinder guides.

To make sure that the lines are at right angles, a strip of wood 6 or 8 ft. long is pointed at each end like a lead pencil, and divided exactly at the middle. Hold this along the main center line with the middle mark at the point where the shaft line crosses, and mark the main center line at each end of the strip. Then hold one end of the strip at one mark, being careful not to push the line sidewise, and bring the other end of the strip to touch the shaft center line, marking the point. Next try the strip from the other mark on the main center line, and see if it touches the shaft center line at the same point as before. If it does, the lines are at right angles, but if not, the outboard bearing must be moved until this test is satisfactory.

The outboard bearing can then be raised or lowered by the adjustment provided by the makers, until a straight edge laid through the main bearing and the outboard bearing shows level.

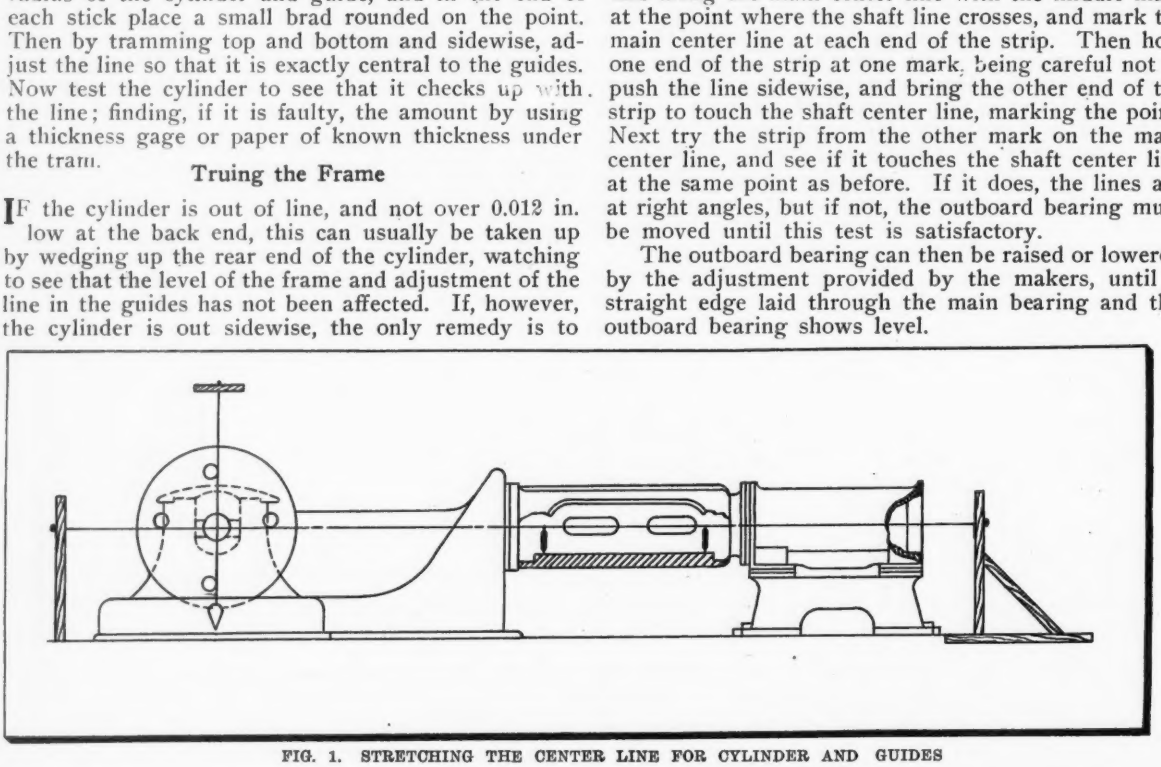


FIG. 1. STRETCHING THE CENTER LINE FOR CYLINDER AND GUIDES

After this last operation, it is desirable to verify the leveling and the lining up of guides and cylinder, the lining up of the main and outboard bearings and their leveling, to make sure that the work has been correct and that no alteration has been made at any point in making the adjustments.

If the lining up is done on an old engine, it may be necessary to rescrape the boxes when replacing the shaft. This can be done by coating the shaft with red lead, laying it in the bearings and revolving it to find where the high points come, and scraping these down until a satisfactory bearing is secured.

In the case of a cross-compound engine, not only must each side be in line with itself, but the 2 sides must be parallel, and both must be square with the shaft. This involves, of course, greater complication and care than in the case of the simple engine, but the method of operation is the same. In the case of a new engine, frequently the distance shown on the blueprints from center to center of the 2 cylinders will not correspond to that in the actual engine, and one side or the other must be shifted the necessary amount to bring each cylinder in line with its crankpin.

Test of Crank and Crankpin

TO test the squaring up of crankpin and crank on the shaft, revolve the shaft until the crankpin touches the line through the cylinder and guides, and measure the distance from the face of the crank to the line. Revolve the shaft until the crankpin touches on the other side, and measure the same distance. Then drop a plumb line through the center of the shaft, just touching the main center line, revolve the crankpin until it touches this plumb line, measure the distance from the line to the crank, revolve the pin to the other vertical position and again measure this distance. The 2 horizontal measurements should be equal and the 2 vertical measurements.

Piston and Crosshead

THE piston and crosshead may now be put in, the piston centered in the cylinder by the junk ring and the distance of the piston rod center from the lower guide be measured. The crosshead shoe should then

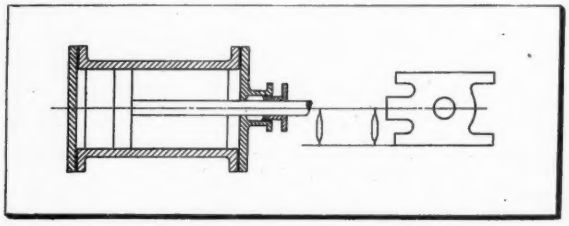


FIG. 3. LINING UP THE CROSSHEAD

be adjusted until the center of the crosshead is at the same distance from the lower guide, when the piston rod may be connected to the crosshead.

Checking Up the Crosshead Pin

THE connecting rod may be attached to the crankpin and keyed up snug, then placing the crank on center, push the crosshead over until the end of the connecting rod rests on top of the crankpin. If the wristpin is in proper line, the end of the connecting rod will be at the same distance from both ends of the crankpin.

Locating the Eccentric

TO line up the eccentric, fasten a line at the middle of the eccentric rod pin, and, holding a square against the shaft, press the line against the other leg of the square near the shaft and move both square and line until the line touches the square throughout its length. Mark the point where the line touches the shaft and on each side of this mark at distances equal to half the thickness of the eccentric make other marks and shift the eccentric to a position between these.

Connect up the engine, being sure that all brasses fit snugly on their pins with a smooth fit. Give the bearings plenty of oil and start up carefully, watching all bearings for any signs of heating. There may be a slight warming up at some points, which will soon disappear, but if any serious heating occurs, the bearing should be tested up carefully to find out where the difficulty lies.

ONE CAN NEVER LOSE the capacity for play without some sacrifice of the capacity for work. The man who never plays may not show any loss of energy, but he inevitably shows loss of power.—Hamilton Mabie.

STEAM PIPING

Methods of Providing for Expansion. Expansion Bends and Joints, Drainage

TEMPERATURE variation from freezing up to as high as 600 deg. F. will cause expansion and contraction in pipe lines which must be taken care of in the design of the system or it will cause trouble at the joints.

Expansion Curves

IN order to save labor of computing expansion of pipe, values have been computed and plotted in the form of curves, as shown in Fig. 2, for wrought iron and steel pipe, for which the coefficient of expansion is practically the same. For cast iron multiply the values given for wrought iron and steel by 0.91; for brass multiply by 1.46

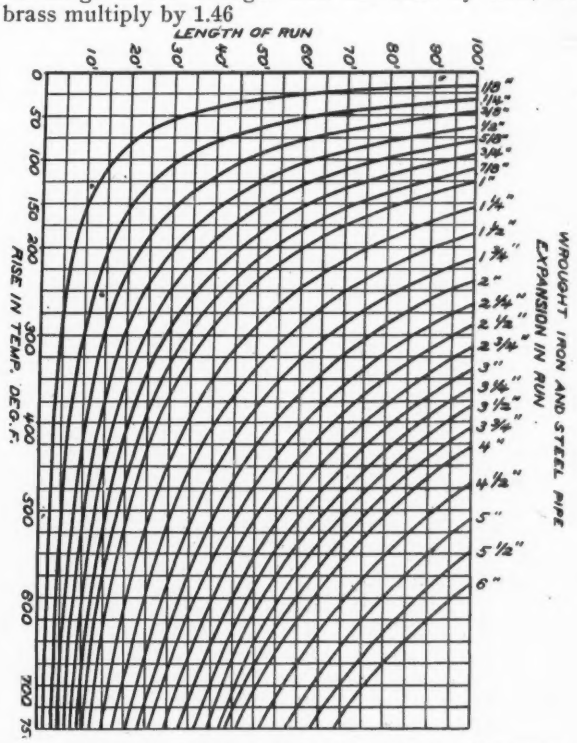


FIG. 2. EXPANSION CURVES FOR WROUGHT IRON AND STEEL PIPES

In general, 4 methods are used for taking care of the come and go due to expansion. One, a swing joint, which may be composed of pipe fittings and nipples if the amount to be taken care of is not great. The second is a slip joint made with a stuffing box and gland, the outer member being usually of steel or iron and the inner tube of brass; the third is a corrugated tube or diaphragm which by its flexibility takes up the movement of the pipe and the fourth is equal length from crown to crown.

The permissible stretch of any form of bend varies with the mean height of loop, is inversely as the square of diameter and independent of practical thickness. Local mechanical considerations govern the exact form of a bend, the loop bend being especially convenient where there is a change of level greater than the pipe diameter.

Expansion Bends

FIGURE 1 illustrates common forms of expansion bends. A bend is more elastic than a straight of equal length from crown to crown.

The pipe bend acts simply as a spring, the distributed bending of the bend serving to take up the motion of the end of the run of pipe; as a certain amount of motion can be taken up by each foot of the pipe may be used. The expansion as shown by the curves is based on a fiber stress of 12,000 lb. in the bends, which gives a factor of safety of 5 to 6 depending on the quality of the metal.

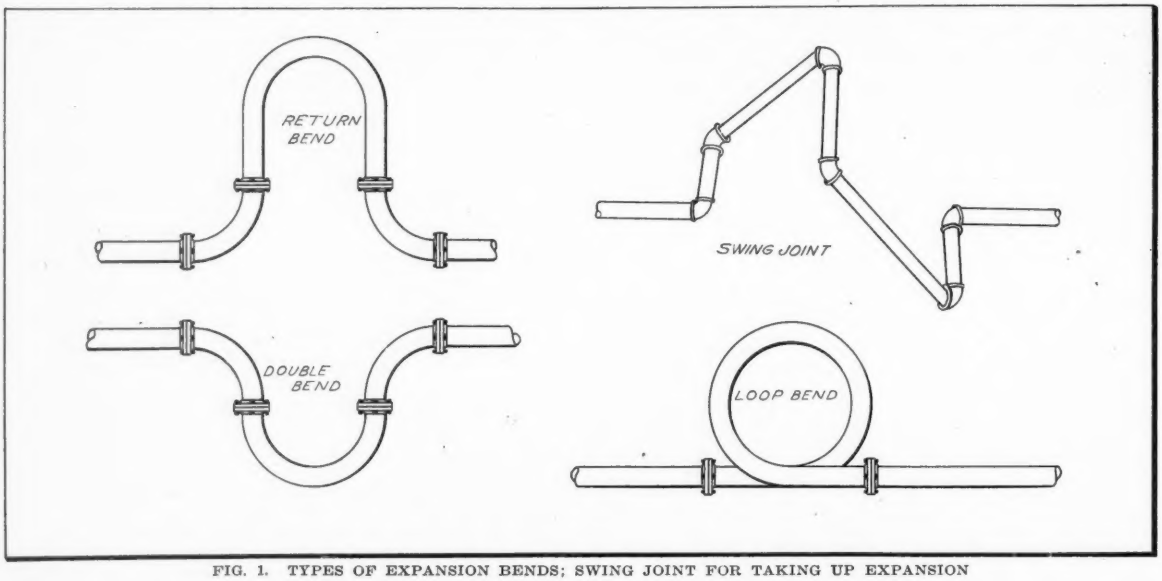


FIG. 1. TYPES OF EXPANSION BENDS; SWING JOINT FOR TAKING UP EXPANSION

bend, it follows that the longer the pipe which is in the bend, the greater is the motion that can be cared for.

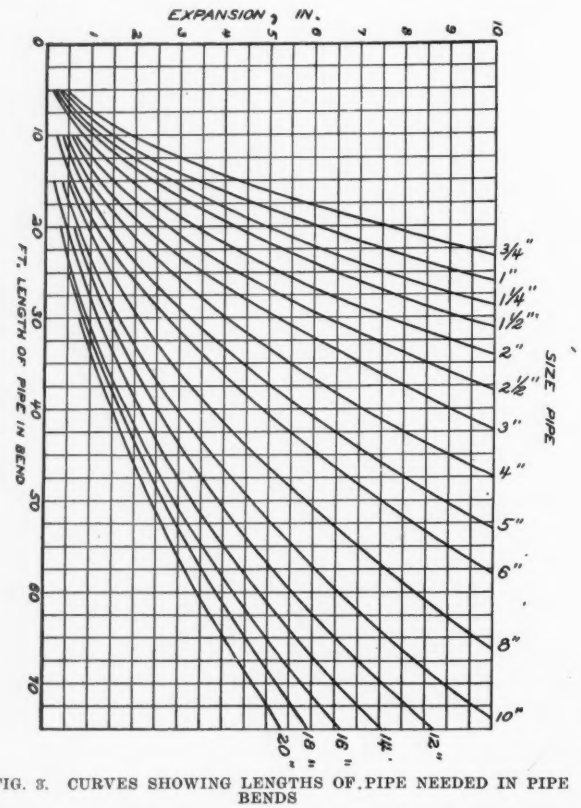
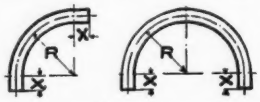


FIG. 3. CURVES SHOWING LENGTHS OF PIPE NEEDED IN PIPE BENDS

In making up a bend, the strain on the metal in bending makes it unwise to use a radius less than 5 pipe diameters, although in extreme cases a smaller

From the curves, Fig. 2, it is possible to get the amount of expansion for any length of pipe run; the curves, Fig. 3 and table in Fig. 4 give the length



Size	Advisable Radius		Minimum Radius	
	R	X	R	X
1	5″	2¼″	2¾″	2¼″
1¼	6¼″	2½″	3″	2½″
1½	7½″	2¾″	3¾″	2¾″
2	10″	3″	5″	3″
2½	1′ 1″	3½″	7″	3½″
3	1′ 2″	4″	8″	4″
3½	1′ 5″	4½″	10″	4½″
4	1′ 7″	5″	1′ 0″	5″
4½	1′ 10″	5½″	1′ 2″	5½″
5	1′ 11″	6″	1′ 3″	6″
6	2′ 6″	6½″	1′ 8″	6½″
7	2′ 10″	7″	2′ 0″	7″
8	3′ 4″	8″	2′ 4″	8″
9	3′ 11″	10″	2′ 11″	10″
10	4′ 6″	1′ 0″	3′ 4″	1′ 0″
12	5′ 4″	1′ 2″	4′ 2″	1′ 2″
14	6′ 9″	1′ 4″	5′ 5″	1′ 4″
15	7′ 2″	1′ 6″	5′ 10″	1′ 6″
16	8′ 0″	1′ 8″	6′ 0″	1′ 8″
18	8′ 10″	2′ 0″	7′ 4″	2′ 0″
20	10′ 0″	2′ 0″	8′ 4″	2′ 0″
22	10′ 10″	2′ 0″	9′ 2″	2′ 0″
24	11′ 10″	2′ 0″	10′ 0″	2′ 0″
26	13′ 10″	2′ 6″	12′ 0″	2′ 6″
28	18′ 0″	2′ 6″	16′ 0″	2′ 6″
30	20′ 0″	2′ 6″	18′ 0″	2′ 6″

FIG. 4. RADIUS AND STRAIGHT ENDS FOR EXPANSION BENDS*

of pipe needed in a bend to take up that expansion, the smallest safe radius and the length of straight end needed beyond the curve.

*The radii and lengths of straight pipe required on each end of a bend here given can be applied to any type of bend. Where the length of curved portion of a bend (taken on center line) plus 2X is greater than the average length of a random length of pipe, the bend must be made in two or more pieces, and the bend designed accordingly.

Drainage

WATER is one of the chief sources of difficulty in a piping system and the greatest precaution should therefore, be taken to make sure that this water will be removed as fast as it enters the system.

Where possible all bends should be horizontal to prevent water pockets. If in a vertical position and the bend extends downward, the pipe must be drained at the lowest level. If the bend extends upward, a drain must be inserted on the supply side of the bend. All pipe lines should be pitched from ¼ to ½ in. in each 10 ft. in the direction of flow of the steam, and at the dead end a drip pocket or drip pipe should be provided.

Pressure Drop in Straight Pipes, Entrance to Pipes, Elbows and Globe Valves

IN every steam pipe line there is a loss of pressure owing to a resistance to the passage of steam through the pipe, bends, valves, and the entrance or opening into the pipe.

$$p_1 - p_2 = \frac{W^2 L}{c^2 w d^5}$$

in which p_1 = pressure of steam in pounds per square inch at the entrance of pipe, p_2 = pressure of steam in pounds per square inch at the exit of pipe; W = weight of steam flowing in pounds a minute; w = density per cubic foot of steam in pounds at the entrance to the pipe; d = diameter of pipe in inches; L = length of pipe in feet. In the formula c is a variable which changes with the pipe diameter, as follows:

Dia. of Pipe, In.	1	2	3	4	6	9	12
Value of c.....	1656.49	2714.41	3457.44	3969	4733.44	5451.89	6288.49

The equation then reads, drop in pressure, $p_1 - p_2$ is equal to the weight of steam per minute squared multiplied by the length of the pipe in feet and this product divided by the continued product of c for the given size of pipe, times the density in pounds per cubic foot of the steam at the entrance of the steam pipe, times the diameter of the pipe raised to its fifth power.

PIPING DIMENSIONS

Rules for Determining the Size of Steam and Exhaust Pipes of Engines

WHEN determining the size of a steam main, a velocity of from 6000 to 8000 ft. a minute is generally accepted as standard practice, although velocities as high as 12,000 ft. a minute have been used in very large power plants. For exhaust pipes a velocity of 4000 ft. a minute is a safe working figure.

In determining the size of the steam and the exhaust piping for a given engine, it is usually considered that it takes steam the full length of the stroke, therefore the length of stroke and piston speed must be known as well as the area of the cylinder. Having obtained these figures multiply the area of the cylinder in square feet by the piston speed in feet per minute, which gives the volume in cubic feet to be filled with steam each minute. This product, divided by the velocity of the steam and multiplied by 144, gives the required area of the pipe in square inches. To figure the area of the exhaust pipe the problem is so! the same manner with the exception that the exhaust velocity is substituted for the steam velocity.

TABLE GIVING STEAM AND EXHAUST PIPE SIZES AND AREAS OF STEAM PORT OPENINGS FOR VARIOUS PISTON SPEEDS

Piston Speed in Feet per Minute	Dia. of Steam Pipe = Dia. of Piston Multiplied by	Dia. of Exhaust Pipe = Dia. of Piston Multiplied by	Full Area of Steam Port = Area of Piston Multiplied by
200	0.183	0.223	0.04
250	0.200	0.248	0.05
300	0.224	0.272	0.06
350	0.242	0.294	0.07
400	0.260	0.314	0.08
450	0.275	0.333	0.09
500	0.290	0.353	0.10
550	0.300	0.368	0.11
600	0.318	0.385	0.12
650	0.328	0.398	0.13
700	0.341	0.412	0.14
750	0.353	0.427	0.15
800	0.365	0.442	0.16
850	0.375	0.454	0.17
900	0.387	0.469	0.18
950	0.397	0.480	0.19
1000	0.408	0.494	0.20

VALVE ACTION

An Explanation of the Cycle of Events in Each Revolution

WHAT is known as the simple D valve takes its name from its resemblance to a capital D, turned with the flat side down and having that side practically all removed. The arrangement is, as shown in Fig. 1, with the ends of the valve the same width as the ports, so that the valve just covers the ports when it stands directly over them or in mid-position. The valve is usually driven by an eccentric. With this mechanism, the center of the eccentric must be at the 90 deg. point on the eccentric circle in order that the valve may be in central position, when the piston is at the beginning of a stroke, as shown in Fig. 1.

Suppose that the direction of running is as shown by the arrow; as soon as the shaft starts turning, the valve will be drawn to the right and the port at the left-hand or head end of the cylinder will be opened to steam, and that at the right-hand or crank end of the cylinder to exhaust. This will force the piston to the right. The further the shaft turns, the more will the valve be moved to the right, until the eccentric center reaches its extreme position at the right of the eccentric circle; then the valve will commence to move to the left. The force of the steam will continue to push the piston to the right, however, until the valve again reaches mid-position and the eccentric is directly at the bottom of the eccentric circle, at which time the piston will have reached its right-hand dead point.

Continuing the motion, the eccentric will move the valve to the left, which will open the right-hand end of the cylinder to steam and the left-hand end to exhaust, thus forcing the piston to the left, the valve coming wider open as the shaft turns until the eccentric reaches its left-hand position. After that, the valve moves to close until the mid-position of the valve is reached and the piston is at the extreme left, as in Fig. 1, and conditions are as at the beginning.

This device will work, but it allows the steam to enter throughout the whole stroke so that there is no chance for it to expand. The engine will work the steam at full pressure, which is too wasteful for any but the smallest and crudest of machinery, hence, something better has to be found. If the valve has a projection, called lap, which extends beyond the edge of the port on the outside end, this will

close the port before the piston reaches the end of the stroke so that the steam will have a chance to work expansively; but this addition also delays the admission of steam at the beginning of the stroke, a condition which is bad, and the eccentric must be turned ahead on the shaft until the admission is brought at the beginning of the stroke. But this turning ahead will further advance the cutoff of the steam. The time of opening and closing the port with

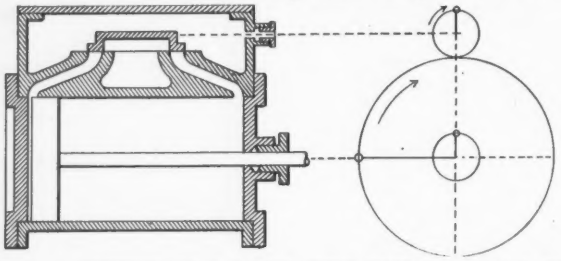


FIG. 1. POSITION OF D VALVE WITH PISTON AT HEAD END OF STROKE

the lengthened valve are shown after the eccentric has been set ahead in Fig. 2.

The more that is added to the valve on the steam end, the earlier will the cutoff come. Also the eccentric will have to be turned farther ahead to bring the admission right, and this again will make the cutoff yet earlier; but also, as the cutoff is thus made earlier, the release of the steam is brought earlier, and the closing of the exhaust earlier so that the compression is greater. These last 2 effects will soon become too extreme to be satisfactory.

When the valve has had something added to it on the end, it will extend beyond or "lap" over the edge of the port as it stands in middle position; and the length that it sticks over is called the "lap" of the valve. Also the angle through which the eccentric is turned ahead to bring the admission right after lap is added is called the lap angle, and is measured ahead of the position the eccentric has when there is no lap, which is 90 deg. ahead of the crank.

Trial and experience show that the practical limit

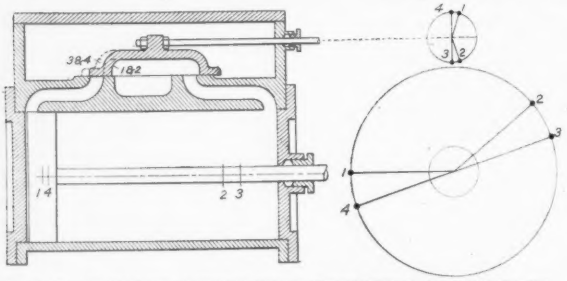


FIG. 2. D VALVE ACTION WITH ECCENTRIC ADVANCED TO CORRECT LATE ADMISSION DUE TO LAP

for cutoff with the D valve is about 5/8 stroke, although a possible action may be had with careful design with cutoff at nearly 1/2 stroke. There is likely, how-

Lead of Valve

AT the beginning of the stroke of the piston it is customary to have the valve slightly open to admit steam, the amount of the opening being known as valve lead. By giving lead to the valve, the work of compression is assisted in bringing the piston to rest at the end of the stroke and also, the clearance space is filled with initial pressure steam soon after the stroke commences.

Setting the Valve

TWO operations are involved when setting the valve of an ordinary slide-valve engine; determining the correct position of the valve on its rod and fastening the eccentric in a position for correct angular advance. To accomplish these results the engine is first placed on its dead center and the eccentric temporarily fastened on the shaft at approximately the place it is to be located, preferably ahead of its true position.

PERIODS OF ADMISSION, OR POINTS OF CUTOFF FOR GIVEN TRAVELS AND LAPS OF SLIDE VALVES

Travel of Valve in Inches	Lead in Inches	Lap in Inches										
		3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2
1 5/8	1/16		19										
1 3/4	1/16		39										
1 7/8	1/16	76	47	17									
2	1/16	77	55	34									
2	3/16	81	70	52	33								
2 1/8	1/16	80	61	42	14								
2 1/4	1/16	80	65	50	30								
2 3/8	1/16	82	68	55	38	13							
2 1/2	1/16	83	71	59	45	27							
2 1/2	1/8	88	80	70	57	43	27						
2 5/8	1/16	85	74	63	49	36	12						
2 3/4	1/16	86	76	67	56	43	26						
2 7/8	1/16	86	78	70	59	47	32	11					
3	1/16	87	80	73	62	50	38	23					
3	1/8	91	86	79	71	61	50	37	23				
3 1/8	1/16	88	81	74	65	55	44	30	10				
3 1/4	1/16	89	83	76	68	59	48	34	22				
3 3/8	1/16	90	84	78	71	62	51	40	29	9			
3 1/2	1/16	90	85	80	73	64	53	45	34	20			
3 1/2	1/8	94	90	84	79	71	63	53	44	32	20		
3 5/8	1/16	91	86	81	75	66	57	49	38	26	9		
3 3/4	1/16	92	87	82	76	68	60	52	42	32	19		
3 7/8	1/16	91	87	83	78	70	63	55	46	36	25		
4	1/16	92	88	84	79	72	66	58	49	40	29		
4	1/8	95	92	88	83	78	72	65	57	39	17		
4 1/8	1/16	92	89	86	81	76	70	63	56	47	37		
4 1/2	1/16	93	90	87	83	79	73	67	61	54	45		
4 1/2	1/8	96	94	90	87	83	78	72	66	59	51	35	14
4 1/2	1/16	94	92	89	85	81	76	70	65	58	31	15	7
5	1/16	95	93	90	87	83	78	73	67	62	36	25	10
5	1/8	97	95	92	89	86	82	77	72	67	61	47	32
5 1/2	1/16	95	94	92	89	86	82	78	73	68	63	55	47
5 1/2	1/8	97	96	94	91	88	85	80	77	72	68	56	43
6	1/16	96	95	93	91	88	85	82	78	74	69	62	56
6	1/4	97	96	94	91	89	86	82	79	75	71	62	50
8	1/4	98	98	96	95	94	92	90	88	86	84	78	72
10	1/4	99	98	98	97	96	95	93	92	90	89	87	82
12	1/4	99	99	98	98	97	96	96	95	94	93	90	88

Measure the lead of the valve and turn it in the direction that it will run until the other dead center is reached and again measure the lead. If there is any difference in the 2 amounts of lead the valve should be moved on the rod one-half the difference to equalize the lead. The next operation is moving the eccentric on the shaft until the port is closed and then in the direction of rotation until the required lead is obtained, finally securing the eccentric in position.

It is advisable to determine the effect of making alterations to existing valves before attempting to change them, therefore the following table will be of value:

EFFECT OF MAKING ALTERATIONS TO EXISTING VALVES

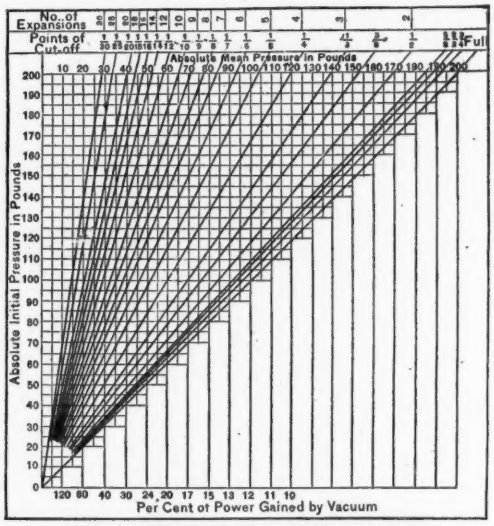
By Increasing the	Admission	Expansion	Exhaust	Compression
Outside Lap.	Occurs later. Ceases earlier.	Occurs earlier. Continues longer.	Remains unchanged.	Begins as before.
Inside Lap.	Remains unchanged.	Begins as before. Continues longer.	Occurs later. Ceases earlier.	Begins sooner. Continues longer.
Angular Advance.	Commences earlier. Period unchanged.	Begins sooner. Period unchanged.	Commences earlier. Period unchanged.	Begins sooner. Period unchanged.

USE OF CONDENSERS

Power Gained by Condensing Engines Over Non-Condensing Engines

BY attaching a condenser to a noncondensing engine a certain percentage of power is gained as shown by the accompanying diagram with a vacuum assumed to be 12 lb. per square inch. The mean pressure in the cylinder for a given initial pressure, zero back pressure and cutoff is also shown, clearance and compression being neglected. All pressures given are absolute above vacuum.

Assume that it is desired to find the actual mean effective pressure produced in an engine cylinder with an absolute initial pressure of 105 lb. with the cutoff at ¼ stroke. Find 105 lb. in the left-hand column of initial absolute pressures and follow to the right until the line corresponding to that pressure intersects the oblique line representing the desired point of cut-


No. of Expansions
Points of Cut-off
Full
Absolute Mean Pressure in Pounds
Absolute Initial Pressure in Pounds
Per Cent of Power Gained by Vacuum

MEAN FORWARD PRESSURE DIAGRAM
(From literature of H. R. Worthington)

off and immediately above the point of intersection find the mean effective pressure, which in this example is 62.5 lb. From this amount subtract the mean absolute back pressure, which we will assume to be 16 lb. for a noncondensing engine, which gives the actual mean effective pressure as 46.5 lb. To find the gain in power by the use of a condenser read the per cent in the lower line under 46.5 lb. in the mean effective pressure line, which is nearly 26 per cent. The results shown by the diagram are approximate as clearance and compression are neglected.

Against this percentage of saving must be put the power required to drive the air-pump. This power ranges from one to 5 per cent of the power of the engine, only reaching the higher limit in very unfavorable situations.

It will thus be seen that wherever water for condensing purposes can be obtained at reasonable cost, a considerable saving may be realized by the use of a condenser, and we therefore recommend its use wherever this condition obtains.

Initial and Back Pressure Changes

WHEN a condenser is connected to an engine that formerly ran noncondensing, other things being equal, the same mean effective pressure will be required in order to get the same amount of work out of the engine. Assume that 27 in. of vacuum is obtained by using the condenser; this would give a back pressure of about 1.5 lb., absolute, while the back pressure when running noncondensing is 14.7 lb.

For 6 per cent clearance and ⅜ cutoff, the mean forward pressure is 0.762 times the initial pressure, absolute, or in the noncondensing engine (assuming initial pressure as 100 lb. gage) $114.7 \times 0.762 = 87.4$ lb. Subtracting 13.2 lb., the difference between back pressure condensing and noncondensing, leaves 74.2 lb. as the mean forward pressure when running condensing. Dividing this by 0.762 gives 97.3 lb. as the initial pressure absolute, which is $97.3 - 14.7 = 82.6$ lb. gage, required to give the same power condensing that 100 lb. gage would give noncondensing.

STEAM ENGINE PROPORTIONS

Pressure on Wearing Surfaces; Sizes of Engine Parts in Relation to Piston

IN the design of steam engines, the pressure on the wearing surfaces has to be taken into consideration when proportioning the various details. The pressure on the several parts is due not only to weight but to the motion of the reciprocating parts acting under the steam pressure. For example, steam pressure on the piston is transmitted to the crankpin through the piston rod and connecting-rod, which may be resolved into 2 components.

One of the components, which acts radially along the crank, exerts a pressure on the main bearings which is in addition to the pressure caused by the weight of the shaft, crank, flywheel, etc. The other component acts at right angles to the crank exerting a tangential pressure, causing the crank to revolve and is known as the crank effort. Crosshead pins are also subjected to pressure from piston and connecting rod.

From experience based on practical design and construction permissible pressures per square inch on the areas obtained by multiplying the length by the diameter of journal, have been deduced which are as follows: Main bearings, 140 to 160 lb.; crank pins, 1000 to 1200 lb.; crosshead pins, 1200 to 1600 lb.

Based on these values and with steam pressures of 100 to 125 lb., the table by James B. Stanwood has been compiled as conforming to common practice.

Relation of Engine Parts to Piston

	Relation to Piston Diam.	Relation to Piston Area
Main Shaft, diameter	0.42—0.50	
Main Shaft, length	0.85—1.00	
Crankpin, diameter	0.22—0.27	
Crankpin, length	0.25—0.30	
Crosshead Pin, diameter	0.18—0.20	
Crosshead Pin, length	0.25—0.30	
Piston Rod, diameter	0.14—0.17	
Steam Port Area:		
Slide Valve Engine		0.08—0.09
High Speed Auto. Engine		0.10—0.12
Corliss Engine		0.07—0.08
Exhaust Port Area:		
Slide Valve Engine		0.15—0.20
High Speed Auto. Engine		0.18—0.22
Corliss Engine		0.10—0.12

Steam Pipe Diameter:

Slide Valve Engine	0.25—0.25+½"
High Speed Auto. Engine	0.33
Corliss Engine	0.30

Exhaust Pipe Diameter:

Slide Valve Engine	0.33
High Speed Auto. Engine	0.375
Corliss Engine	0.33—0.375

	Per Cent Piston Displacement
Clearance space:	
Slide Valve Engine	6—8
High Speed Auto. Eng., 1 valve	8—15
High Speed Auto. Eng., 2 valves	3—5
Corliss Engine	2—4

	Lb. per rated Horsepower
Weights of Engines:	
Slide Valve	125—135
H. S. Auto.	90—120
Corliss	220—250
Weights of Flywheels:	
Slide Valve Engines	33
High Speed Auto. Engine	25—33
Corliss	80—120

Rules for Flywheel Weights, Single-Cylinder Engines

Let d = diameter of cylinder in inches;
S = stroke of cylinder in inches;
D = diameter of flywheel in feet;
R = revolutions per minute;
W = weight of flywheel in pounds.

For slide-valve engines, ordinary duty

$$W = 350{,}000 \frac{d^2 S}{D^2 R^2}$$

For slide-valve engines, electric lighting,

$$W = 700{,}000 \frac{d^2 S}{D^2 R^2}$$

For automatic high-speed engines,

$$W = 1{,}000{,}000 \frac{d^2 S}{D^2 R^2}$$

For Corliss engines, ordinary duty,

$$W = 700{,}000 \frac{d^2 S}{D^2 R^2}$$

For Corliss engines, electric lighting,

$$W = 1{,}000{,}000 \frac{d^2 S}{D^2 R^2}$$

SLIDE VALVE DIAGRAM

Method of Finding Outside Lap, Per Cent Cutoff and Maximum Steam Port Opening

ACCOMPANYING diagram shows the relations existing between cutoff, port opening and outside lap. If 2 of the 3 are known the third can be readily found. The horizontal lines represent the points of cutoff, in per cent, the vertical lines, outside lap in inches, and the curves maximum steam port opening in inches. When the outside lap and cutoff are given or assumed, to find the maximum port opening, from the point of cutoff at the left, follow the line horizontally to the right until it intersects the vertical line corresponding to the outside lap and the curve passing that point will give the maximum port opening in inches.

To find the point of cutoff when the maximum steam port opening and outside lap are known, follow the vertical line corresponding to the outside lap, until it intersects the curve corresponding to the port opening, then follow the horizontal line to the left and read the point of cutoff.

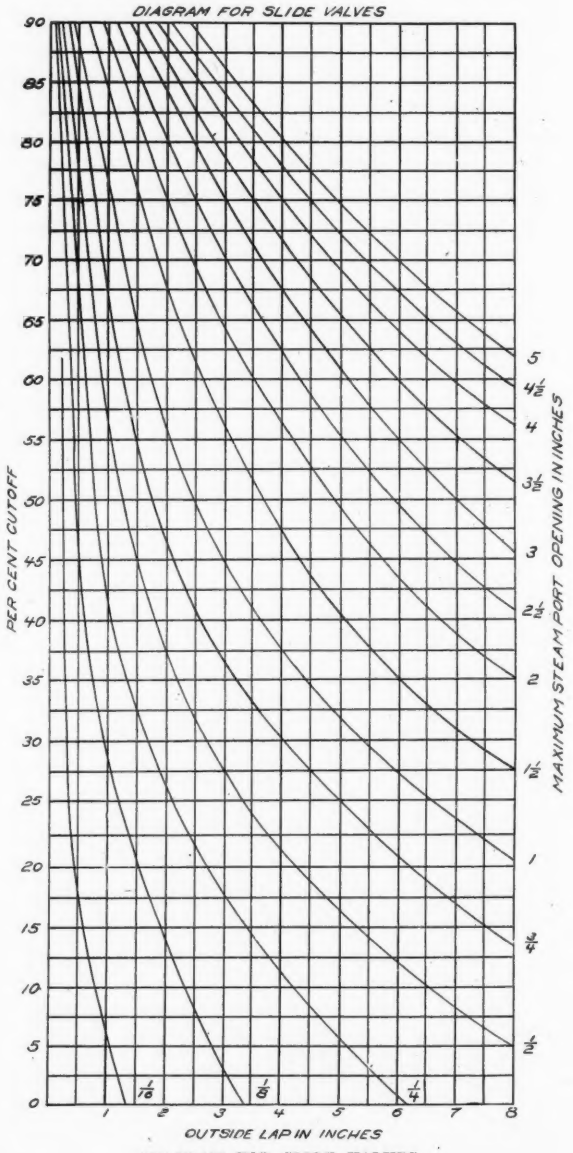


DIAGRAM FOR SLIDE VALVES

To find the outside lap when cutoff and port opening are known, follow the horizontal corresponding to given cutoff to its intersection with the curve for given port opening; then drop vertically and read the lap required.

No MAN can hope to accomplish anything great in this world until he throws his whole soul, flings the force of his whole life into it.—Orison Swett Marden.

THE SINGLE VALVE ENGINE

Types of Valves and their Advantages. Setting the Piston Valve and the Shifting Eccentric Gear

AS explained in a previous section, the D valve answers all requirements of admitting and exhausting steam, but it is limited in its range of cutoff and as the pressure on the back is unbalanced, when used in large sizes, considerable power is used up in friction between the valve and its seat. The action of the valve in opening and closing is gradual so that free passage for steam is secured only after an appreciable interval.

To overcome these defects, various devices are resorted to; balancing of pressure may be secured by a pressure plate over the back of the valve which is carried on strips at the side, openings being made through the valve so that the same pressure acts on both sides as in the Sweet valve used on the Ames engine. Or a piston valve may be used, running in a cylindrical seat, giving equalized pressure all around as in the Ideal engine.

Still another form of balancing is the 2-part valve, arranged so that one face bears on the seat and the other on the steam chest cover, the parts being separated to maintain their bearing by steam pressure as in the American Ball and the Skinner engines.

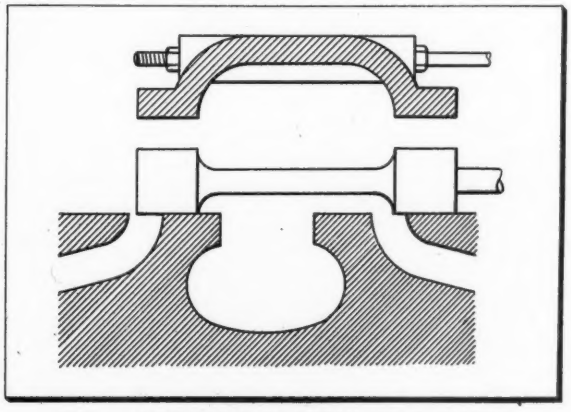


FIG. 1. COMPARISON OF PISTON AND D VALVES

Quicker opening and closing are secured by the use of several openings at each end of the valve, as in the Sweet valve already mentioned and the Ridgway engine, or in multivalved engines by a system of links to multiply the rapidity of motion. The single valve does not lend itself readily to such multiplying action, and extreme rapidity of opening and closing are not of so great consequence for the exhaust events as for the steam events.

Range of cutoff is provided by the shaft governor which shifts or rotates the eccentric so as to change the valve travel or the timing of the valve, which makes the range limited only by the advisable governor motion, usually from practically zero up to ¾ or ⅞ stroke.

The action of the flat balanced valve is the same as that of the D valve, and the method of setting is the same; in case of the multiported valve, only one edge at each end need be considered, as all ports at one end should open and close at the same instant if the valve is properly made. By removing the steam chest cover and balancing plate, the valve and seat are in full view and can be got at even more readily than a D valve to determine the action.

Piston Valve Setting

FOR the piston valve, it is necessary to work by measurement, since the valve seat is not get-at-able in making adjustments.

Reference to Fig. 1 will show the relation of the parts of D and piston valves. The action is exactly the same, and, of course, either one may be arranged to take steam on the inside and exhaust at the end. This arrangement is, however, unusual with the D

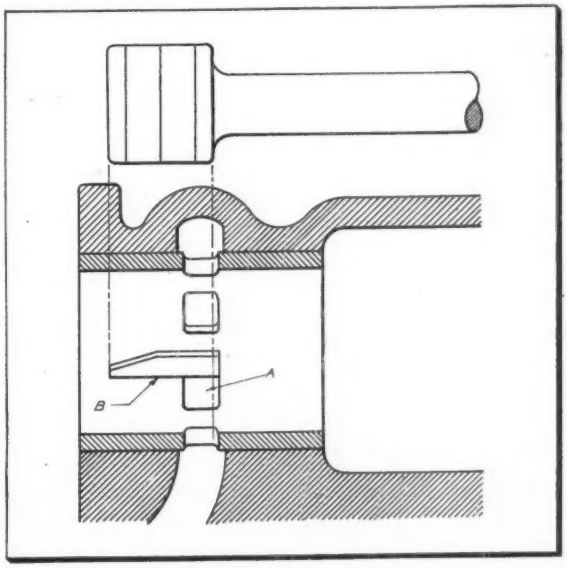


FIG. 2. FINDING THE LEAD OF A PISTON VALVE

valve, but quite common with the piston type, as it avoids high pressure steam against the valve stem stuffing box. The directions for setting will, therefore, be given for a valve taking steam inside.

First, place the eccentric on the inner dead center and scribe a mark on the valve stem and guide to enable returning to the original position if necessary.

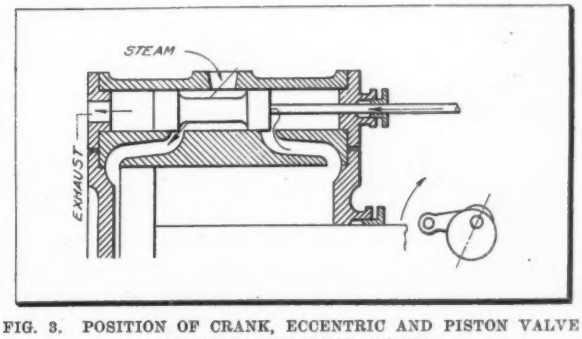


FIG. 3. POSITION OF CRANK, ECCENTRIC AND PISTON VALVE AT HEAD END DEAD POINT

Next disconnect valve stem from guide block, take off the back steam chest cover and pull out valve and stem. Then take off the other chest cover. A piece of thin sheet iron should be cut and the edges dressed up about 1 in. wide and as long as one valve head plus

the lead (1/32 to 3/32 in.). If the valve heads are not the same length make a sheet iron templet for each and mark them carefully, Crank and Head.

Place one end of the head end templet against the inside edge of the head end port as in Fig. 2, and scribe a fine mark at the other end of the templet. Do the same thing with the crank end templet at the crank end port. Then replace the valve, leaving the covers off and connect up to the eccentric.

It should be remembered that taking steam on the inside end of the valve calls for a motion the reverse of that when steam comes from the outside; i. e., the eccentric will follow the crank at an angle of 90 deg. less the angle of advance.

Place the crank on head end dead center and turn the eccentric on the shaft until the outer edge of the valve is just at the scribed mark and make fast to the shaft. The port will then be open by the amount of lead selected when making the templet.

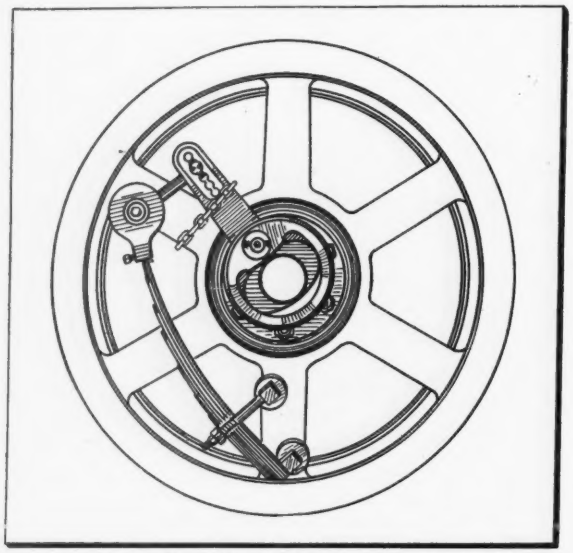


FIG. 4. SHAFT GOVERNOR BLOCKED AT RUNNING POSITION FOR SETTING OF VALVE

Turn the engine over to the crank end dead center, and the edge of the crank end of the valve should be just on its scribed mark. If it falls short of the mark, the lead on the crank end is less than that for the head end. If it extends beyond the mark, the crank end lead is the larger. In either case the lead should be equalized by adjusting the length of the valve stem or changing the position of the valve on the rod by half the difference between the leads on the 2 ends. Then replace the steam chest covers.

Verification of correct valve action by means of the indicator is always desirable, making such changes in valve stem length and eccentric position as the diagrams show to be wise.

Setting the Valve with Shaft Governor

MOST engines are rated at about ¼ cutoff, hence, when setting a valve which is driven by a shifting eccentric the governor should be blocked out to a position that will give that cutoff. The operation is then the same as for the D valve with fixed eccentric, allowing, of course, for reversal of motion if a reversing rocker is used between eccentric and valve, as for instance in the case of the Ames center crank engine.

The engine should be turned over after the valve is set and the crosshead position noted for cutoff at each end. Sometimes it is desirable to adjust for somewhat greater lead to the crank end in order to bring the cutoffs more nearly equal, but head end lead should never be cut down so as to show late on the diagram, and the lead should never be so large as to cause racing at light loads.

If the governor is so made or located that it can not be blocked out, the setting may be made with the governor at the innermost position, as the division of lead between the ends is not greatly altered by the change in position of the governor, and the exact division of lead for best action can be determined from the indicator diagrams.

If the governor turns the engine around the shaft to alter the lead, as in some older engines, the valve is set the same as the D valve with governor in innermost position.

The descriptions of single valve engines following give a clear idea of all modern valves and governors as well as other details.

A. B. C. VERTICAL ENGINES

American Blower Co., Detroit, Mich.

THIS engine was designed to provide a high speed small engine for continuous hard service such as driving blowers, generators for lighting and exciter sets, centrifugal pumps, conveyors and hoists.

In this engine frame the easy curves and graceful lines will attract the attention of every engineer as being beautiful and easily cared for. The base of the engine is large, assuring stability and rigidity as well as increasing the surface for radiating heat and settling any impurities out of the oil. The enclosing plates are easily removed by simply turning a milled hand nut, which leaves all the interior parts easily accessible.

The stuffing box, which is not enclosed, can be inspected at any time, and this arrangement prevents the heat from the steam communicating to the oil space.

The cylinder has short and direct ports, with piston rings over-running the counter bore. The seat for the valve is first bored and reamed on the machine and afterward reamed by a sizing reamer by hand, to secure a fit which will prevent steam from blowing through between valve and seat. The piston valve is ground between centers to standard diameter, and takes a very fine finish.

Drain cocks of the automatic relief type will automatically open, relieving the engine of undue strain and avoiding possible wreckage.

The piston is pressed on the rod against a collar, which is left of good size when turning the rod, and is secured by a standard nut screwed down tight with the remaining projection of the rod riveted over the nut.

Crosshead pin brasses in the connecting rod have the same composition as the shoes and will not cut with the pin; adjustment being a standard wedge locked by 2 cap bolts on the larger sizes, and by a lock nut on the smaller. Crank brasses, lined with babbitt metal, are held in a marine type rod end, both crosshead and crank brasses being 1/32 in. shorter than the pins, so the rod may slide endways along the pins to make sure they are not drawn too tight when adjusting.

To adjust the crank end, the lock nut is loosened, then the head of the connecting rod bolt (not a nut) may be turned, drawing up the cap as the bolt is

threaded into the cap. The exact adjustment is determined by sliding the rod endways on the crank-pin, and tightening the lock nut does not affect this adjustment.

The flywheel is so designed that the greater part of the weight comes in a plane close up to the end of the main bearing, and relieving to that extent the breaking strains in the shaft. The internal flanges retain water that may drip and splash into it, and add to the strength of the wheel.

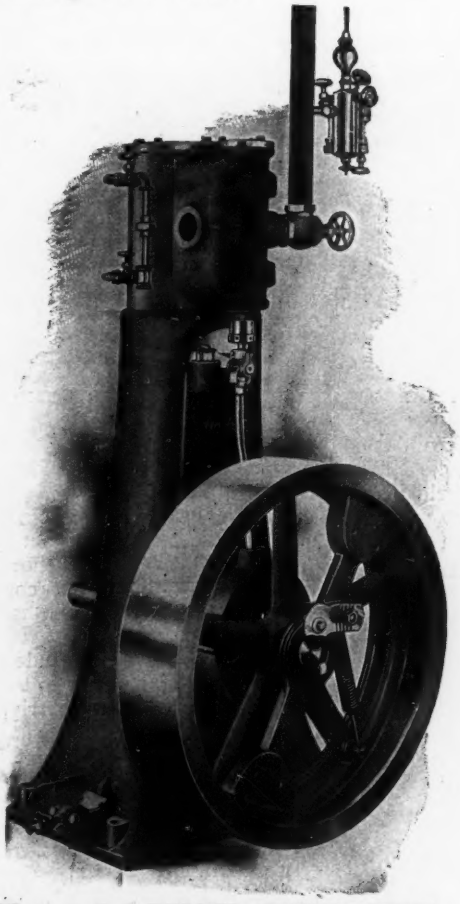


FIG. 1. A. B. C. ENCLOSED AUTOMATIC ENGINE

The Rites inertia governor has a special device attached to it by which the spring lever arm can be shifted, to change the speed of the engine either faster or slower and still retain perfect regulation, within one per cent from no load to full load. The weight arm is placed on the side away from the engine, so it is easy to adjust when changing the speed.

Before starting a new engine, a quantity of warm water and oil is put into the engine base, sufficient to surround the strainer located in the center of the base, Fig. 2. This is drawn into the pump as it revolves and discharged into the large vertical pipe, which conveys the oil to the top of the frame, emptying through a glass cup located oustide where the flow can be easily seen. This cup discharges through a strainer into an oil pan to which brass oil tubes are attached for distributing oil to the various bearings and wearing surfaces, the tubes projecting up to the top, with a narrow slit cut down one side of each, to cause an equal flow of oil into each tube and prevent scale, lint or dirt getting into them.

One short tube carries oil into an oil-boat on the crosshead pin, from which the oil drops on oil trays, attached one to the enclosing panel on each side of the frame. From these trays spouts conduct the oil to cups cast in the tops of the main bearings, whence it runs along the oil grooves in the bearings.

On the governor side, the oil goes from the bearing into the eccentric, passing through a groove in the eccentric to the governor-weight pin, and along the pin to the opposite end, whence it flows into a channel drilled in the hub of the flywheel back into the tray beneath the eccentric, and downward through a channel cored in the supporting web beneath the main bearing into the oil reservoir in the base.

In the other bearing, oil simply traverses the bearing into a groove and thence into the base. By another tube oil from the pan at the top of the frame is carried to another channel in the main bearing on the flywheel side, and into a deep groove cut into the side of the large bronze worm on the engine shaft, which by centrifugal force forces the oil into a channel cut across the face of the crank-pin.

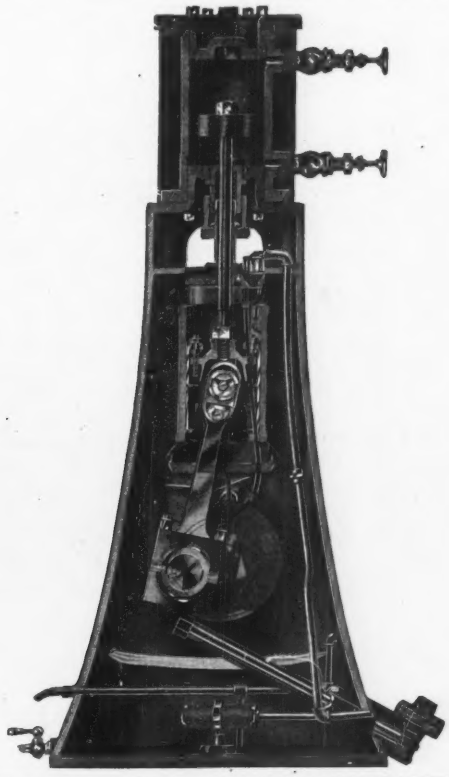


FIG. 2. VERTICAL SECTION SHOWING OILING SYSTEM

Through a large groove on each side where the halves of the crank-pin brasses join, oil is admitted to the surface twice per revolution and, escaping from the opposite side of the crank-pin, drips onto a filter cloth suspended beneath it, from which it drips into the oil reservoir.

Two other short tubes carry oil into channels leading to grooves cut diagonally across the faces of the ways, after lubricating which the oil joins that from the crosshead pin.

This system allows every bearing to be so loose that the shaft or pin can be easily moved by hand, giving a film so thick that there is absolutely no contact between metals.

The pump is a simple bronze gear, accurately cut, and fitting close to the surrounding case. Having no valves or other loose parts, it requires no attention.

In the A. B. C. double engine the construction is the same except that a single valve between the 2 cylinders controls steam distribution to both, and the governor is mounted inside the frame between the cranks, which are double throw.

These engines are built in sizes from 3¼ by 3 in. single to 9 by 8 in. double cylinder, giving capacities from 1¼ to 120 hp.

AMERICAN-BALL ENGINE

American Engine Co., Bound Brook, N. J.

THIS engine is of center crank type with open top frame, and planed guides mounted top and bottom of the crosshead on planed seats, the guides thus being adjustable and permitting of a solid crosshead.

The crankshaft is forged of steel with heavy and rigid cranks, to which the counter-balances are secured by large studs and nuts, Fig. 4, providing an easy method of adjusting the counter-balance to the conditions of the foundation by substituting heavier or lighter counterweights, as the case may require.

In the shaft governor, 2 features attract attention; the method of establishing a gravity balance, and the arrangement and relation of the springs.

Besides the single pivoted arm, a second arm is so pivoted that its center of gravity is practically on the axis of the shaft, and, therefore, develops no centrifugal force. This second arm is so connected to the governing or centrifugal arm that the gravity of one is always opposed by the gravity of the other at every position of the wheel. Hence the centrifugal force of the governing arm under the control of the springs is made to govern the engine, while the disturbing gravitation of this arm is neutralized or balanced by the opposing gravity of the second arm, which, as before stated, has practically no centrifugal force.

FIG. 1. SIMPLE AMERICAN-BALL ENGINE

Use of double springs prevents swaying or bellying, and aids in the delicate balancing of the governing forces. These springs are convenient, also, for slight adjustments of what is known as the "characteristic" of the governor, or in other words the real difference in speed at the several points of cutoff. Generally speaking, and within limits, the slacking of the radial spring and the tightening of the other reduces the drop in speed under load, and the reverse adjustment increases it, which is often convenient where several engines are to be adjusted to run in parallel service and it is desired to make each take its share of the load.

The valve consists of 2 parts which are in reality 2 valves with telescopic sleeves connecting their backs and forming a continuous passage. The 2 faces of this double valve perform similar functions on opposite seats in the steam chest, which seats are duplicates of each other in regard to the ports.

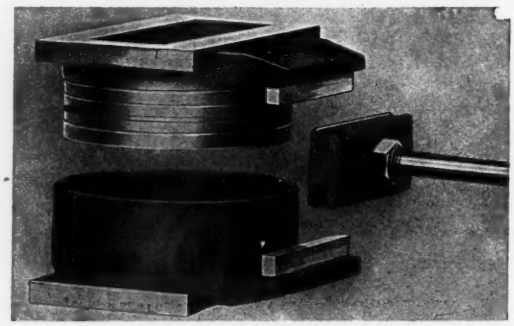


FIG. 2. BALANCED VALVE WITH PARTS SEPARATED

Steam is admitted at the top of the steam chest into the interior of the valve. The faces of the valves are held in contact with their corresponding seats by steam pressure, that diameter of the telescopic sleeves being selected which insures positive contact between the valve and its seats in all positions without undue friction; the telescopic action insures a continuous contact with a minimum of wear which is "taken up" automatically.

A convenient reducing motion is included in the design of the engine, and is always ready to be thrown into action or immediately stopped by a trigger.

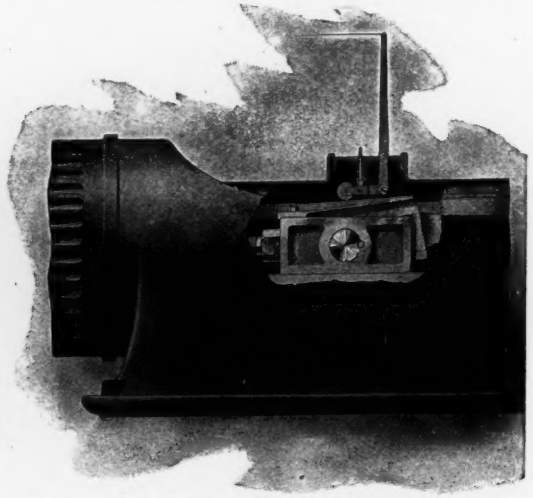


FIG. 3. BUILT IN REDUCING MOTION (PATENTED)

In the angle-compound arrangement, 2 engines, one horizontal and one vertical, connect to the same crankpin, so that the inertia forces of each engine are made to neutralize those in the other.

This general arrangement is illustrated in Fig. 4, which is a sectional view showing the reciprocating parts of the 2 engines, whose connecting-rods are

placed side by side on a crank-pin of double the usual length, this crank-pin being part of a crank-shaft having pillow block bearings at both sides so that all thrusts are carried between these bearings and not on overhanging parts.

The counterweights attached to the heel of the crank are made sufficient to balance the inertia thrusts of the horizontal reciprocating parts when passing the horizontal centers, and the same counterweights balance the vertical thrusts of the vertical parts when passing the vertical centers, thus the sum of these thrusts is practically balanced by the counterweight at all times.

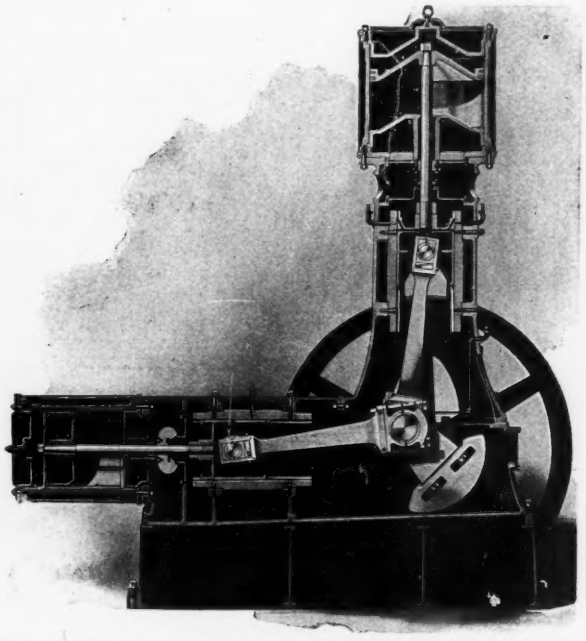


FIG. 4. SECTION OF AMERICAN-BALL ANGLE-COMPOUND ENGINE

The turning effort on the shaft is steadied; lighter flywheels may be used; and with the use of a bypass to the low-pressure cylinder the engine is always in position to turn the crank; the engine occupies small floor-space in proportion to the power.

Mechanical details are, with slight modifications, the same as for the simple engine, the low-pressure valve being driven by separate fixed eccentric.

THE BALL SIDE CRANK ENGINE

Ball Engine Co., Erie, Pa.

THESE engines are built in the following types: Horizontal single cylinder, tandem compound, cross compound, vertical single cylinder and cross compound, from 80 to 800 horsepower.

The side crank construction has been adopted because of its superior adaptation to usual conditions of service. The frames are heavy, and the design—by a scientific disposition of the metal—is such as to give great strength and rigidity.

Means are provided to keep the shaft always in alinement. To those who realize how necessary alinement is for correct operation, and how seldom it is maintained in service, the value of this is apparent.

The oiling system furnishes a reliable means of supplying oil to the bearings in any quantity desired. Adjustable sight feeds are provided at each bearing, and these are piped together and coupled to a tank mounted on the top of the frame, and provided with filter. A valveless pump of a special type, which cannot be choked by waste or foreign substance, automatically pumps the used oil back into the tank.

The main bearing boxes are designed so they do not quite touch the shaft. The oil is drawn into this

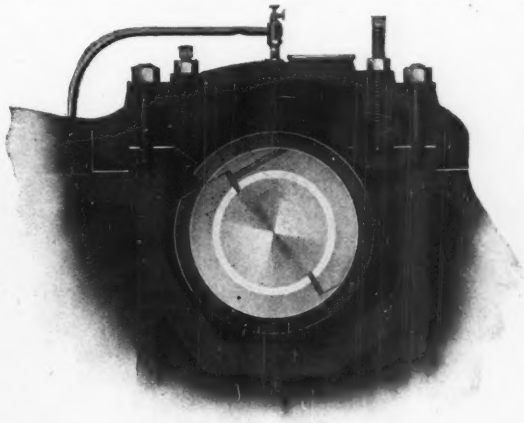


FIG. 2. 2-PART MAIN BEARING

capillary space by the rotation of the shaft, and as the space gradually lessens in the direction of rotation it forms a powerful pump, capable of forcing the oil in against enormous pressure. The boxes are solidly locked in position, yet may be readily adjusted while the engine is in motion. The lower box can be conveniently removed by raising the shaft a small amount.

The crosshead is provided with removable shoes secured in such a manner as to prevent any possibility of their getting loose, and the wearing surfaces faced with genuine babbit. The adjustment for wear does not shift the shoe endwise, consequently they are always central with the crosshead pin. The crosshead runs in bored guides of large wearing area. The center of the crosshead pin is of forged steel and the outside of a special mixture selected for its exceptional wearing qualities, and is so arranged that it

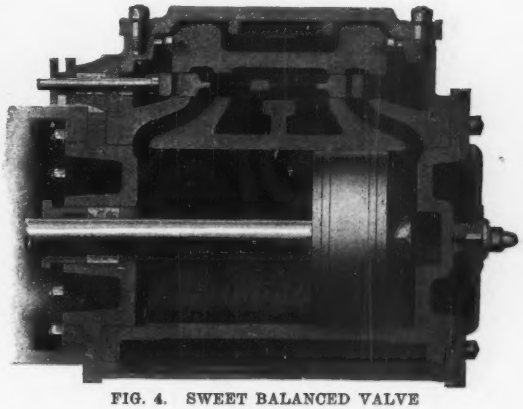


FIG. 4. SWEET BALANCED VALVE

can be given a new surface for wear. This, in connection with the excellent wearing qualities of the pin and the unusually copious lubrication eliminates the troubles ordinarily experienced with crosshead pins and boxes.

The connecting rod is a single steel forging with ends bored and slotted for the boxes. The crank boxes are lined with hard genuine babbitt. The crosshead boxes are of a special anti-friction bronze, having practically the same coefficient of expansion as steel and iron so that all parts expand alike. Wedge adjustments are provided and the wedges are adjusted by bolts threaded entirely through the wedges, and of a larger size than ordinarily used.

The crank shaft is a single forging of high carbon open hearth steel, ground to smooth and accurate running surfaces. The crank and pin are cast integral of a special mixture of iron and steel, having great strength and superior wearing qualities.

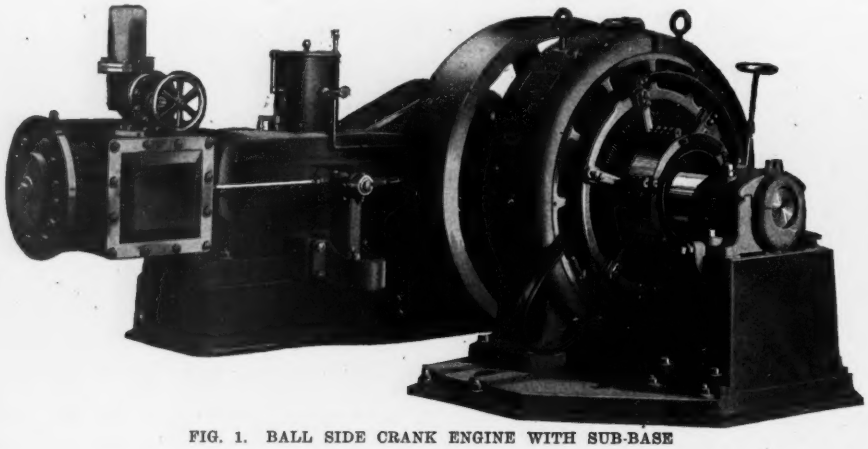


FIG. 1. BALL SIDE CRANK ENGINE WITH SUB-BASE

The R. A. S. governor used in Ball engines carries the weight directly on the spring, and does not transmit its centrifugal stress through any bearing, thus eliminating the troubles caused by friction which affect other governors.

It has a powerful spring, which means a powerful governor, not affected by the ordinary friction of the valves and valve gear. Its adjustments are so simple and certain that they do not require an expert. There are but two simple adjustments, one for controlling the speed, the other for regulation, both of which are easily made, and when made are permanent.

The valve is of the flat balanced type, and has less clearance than any other used in single valve engines.

Means are provided by which the valve may be readily and accurately adjusted to take up any wear that may occur. With no greater skill than that employed in adjusting the connecting rod boxes of the engine, the valve can be kept steam tight during the lifetime of the engine. This device is patented and used exclusively on Ball engines.

A METHOD WHICH has been found satisfactory for filling bearing grooves with graphite is as follows: Take silicate of sodium and reduce with water to about the consistency of thin maple syrup and add enough graphite to make a thick paste. This paste should be quickly pressed into the grooves of the casting, as it hardens very rapidly, and the casting should then be dried in a very slow oven, for if the heat is intense it will cause the paste to blister.

BUFFALO SIDE AND CENTER CRANK ENGINES

Buffalo Forge Co., Buffalo, N. Y.

BUFFALO horizontal engines are built in both the side crank and center crank types, and in 2 classes, differing only as to the method of lubrication. Class B engines are provided with large sight feed oil cups, and are recommended for such low speeds as will not allow of splash lubrication. Class A engines, enclosed, run in oil and use the splash system of lubrication.

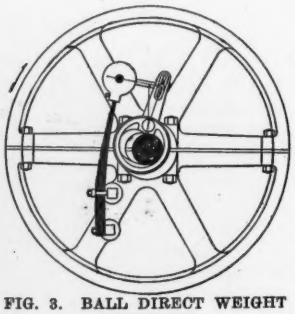


FIG. 3. BALL DIRECT WEIGHT GOVERNOR

Lubrication of both types of engines is the same, and the construction differs only so far as each type demands. The engine frame is a one-piece casting, being a combination of the tangye and girder types, designed for strength and compactness. Guides are of the bored type, cast solid with the frame, which is supported by a substantial sub-base constructed so as to receive in a groove any waste oil, and prevent its dripping down the sides.

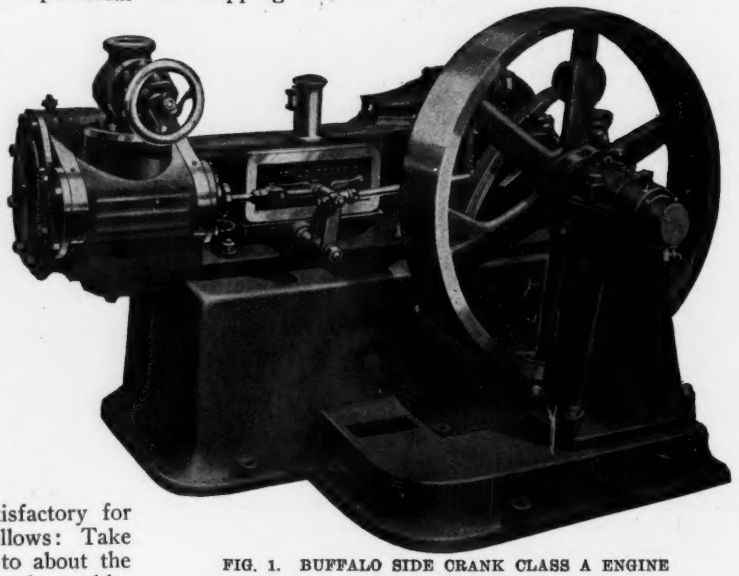


FIG. 1. BUFFALO SIDE CRANK CLASS A ENGINE

The crank shaft is forged in one piece of open-hearth steel, with cast-iron disks, carrying counterbalance weights, built solidly onto the crank forgings. The crank is counterweighted so correctly that the engine will run without vibration. For side crank

engines the shaft is forged steel with a cast-iron disk shrunk on.

The crosshead has shoes which are filled with best babbit metal and accurately fitted to the guides, tapered and fastened to the crosshead proper with a screw and lock nut attachment to take up wear.

The outboard bearing is cast integral with the pedestal and ball and socket liners insure correct alinement.

The connecting rod is forged of open-hearth steel, slotted at the crosshead end for solid brass boxes, and with wedge adjustment. The same method is also employed at the crank end, which in design is of the locomotive type.

Cylinder and valve chest are cast in one piece, and protected with polished sheet metal lagging, enclosing a space for insulation. Ports are of ample area, short and direct, to reduce clearance to a minimum.

A perfectly balanced piston valve is used consisting of 2 heads, each provided with a special snap ring which insures perfect seating, and expands to take up the wear. The valve pistons are mounted on a common rod of size to make them rigid, and may be adjusted independently. The valve seat is formed by 2 removable bushings, carefully reamed to fit the valve. Automatic relief valves of special design are supplied for guarding against damage due to water in the cylinder. Rocker arm motion is used on engines of 14-in. stroke and over to drive the valve, and on engines of 12-in. stroke and under, a ram is used instead of a rocker arm.

The governor has but 3 moving parts, eccentric, link and spring. The eccentric is supported by and swings on a steel pin, which passes through the governor wheel hub and is secured by a nut at the outer end. It is provided with a slotted arm, and a pin through the slot connects it with a link connected to the governor weight and provided with spherical bearings at each end, to insure alinement. The guarantee of regulation is 1.5 per cent speed variation from no load to full load.

In the compound type, the low-pressure valve is of flat slide type, double ported and balanced with pressure plate, and driven from a fixed eccentric.

Other types of engines are built by the company with plain slide valve, throttling governor and box girder bed to meet requirements of minimum expense, and all types are built in vertical arrangement, the details except frame being the same as for the horizontal engines.

BATES VERTICAL ENGINE

The Bates Machine Co., Joliet, Ill.

FULLY enclosed, with removable valve bushings, this engine is neat in appearance and rigid in construction. The frame is a solid casting carrying guides, bearings and oil reservoir, stiffened in front by a removable strut rod allowing easy access to shaft and bearings when making repairs.

The shaft, with center crankpin, larger in diameter than the shaft, gives a rigid construction that maintains alinement, and ring-oiling, 2-part bearings give long life and generous lubrication.

At the crosshead, the connecting rod is of closed end type with bronze bushings, and at the crank end of marine type with babbitted boxes.

Oil passes from the bearings to the reservoir in the bottom of the frame, whence it drains to a separator which removes the water, then to an oil filter and is returned by a force pump to a reservoir located on the cylinder. Through a multiple sight feed it is conducted by a system of pipes to the bearings and repeats its course.

A double ported piston valve controlled by a Rites governor regulates steam supply and exhaust.

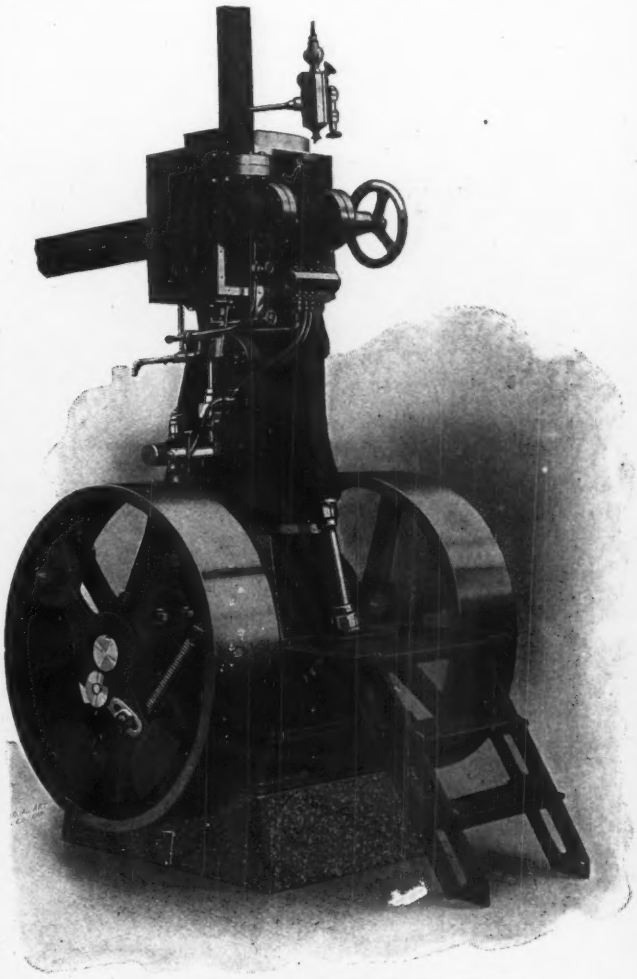


FIG. 1. BATES VERTICAL HIGH-SPEED ENGINE

The Bates engine is built in simple and compound arrangement in sizes from 25 to 500 hp. at speeds of 375 to 180 r.p.m.

THE BROWNELL ENCLOSED SELF OILING AUTOMATIC ENGINE

The Brownell Co., Dayton, O.

ENTIRELY new designs of engines made by this Company have recently been completed embodying many new features and advantages. Arrangement to obtain any cylinder bore or stroke desired, ability to fit any cylinder or any flywheel to any frame and interchangeable manufacture to templates and gauges, give great flexibility as to speeds, pressures, and powers.

In the frame, extra metal is used and where necessary, extra internal ribs are provided to stiffen the frame, and into which impurities may flow, insuring solid metal at all important points.

A single-piece massive frame carries a heavy main bearing. Between the guides and the cylinder is a space forming a chamber into which oil and water from the stuffing boxes drain and are carried to a pan in the base of the frame where it can be drawn off at any time, filtered and used again.

Great care has been taken to confine the oil which is used on the splash oiling system. The bottom of the cover plate which closes the opening to the crosshead fits into a cast-iron groove draining to the guide chamber,

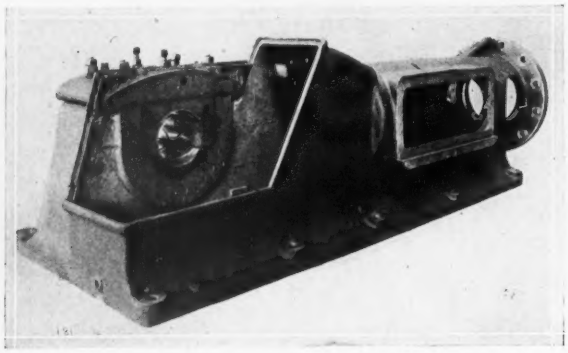


FIG. 1. FRAME OF THE BROWNELL ENGINE, SHOWING OIL GROOVE BELOW THE COVER PLATE; RESERVOIR IN CRANK CASE FROM WHICH OIL IS FED TO THE GUIDES AND VALVE ROD GUIDE BAR.

from where the oil is carried by gravity to the main oil reservoir. There is also a covering or casing over the eccentric which carries the oil to the main reservoir.

The four-part main bearing has extra large bearing area, insuring cool bearings. The bottom piece fits a bored seat with a tongue and groove. This prevents end motion. Both side pieces are adjusted by wedges at each end bearing against distance pieces, and controlled by bolts through the cap. The top piece is adjusted by liners and is held down by jam screws through the cap.

All pieces are babbitted and with oil grooves which start from the upper edge, but do not carry quite to the lower edge, so that the grooves must fill before the oil will be wiped across the bridge into the reservoir, formed by beveling back the quarter box edges from which the next grooves below take their supply.

Enclosing the crank disk which is forced on the shaft by hydraulic pressure, is a casing of planished steel and polished angles. This casing is vented by a hole in the upper handle having an L outlet, so that the oil is not forced out. This avoids any "breathing" of the case.

The solid end connecting rod has split boxes with wedge adjustment in the same direction, and turns on a crosshead pin held into the head by a flange and 4 clamp bolts and adjusted for any slight wear by 2 distance screws through the flange and bearing on the crosshead. This also serves to remove the pin which can be turned 90 deg. to insure even wear on the pin.

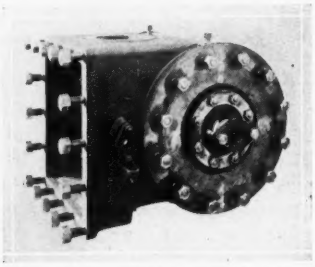


FIG. 2. CYLINDER AND STEAM CHEST CASTING, SHOWING CENTERING RING, PISTON ROD, STUFFING BOX, AND CARRYING FLANGE, AND THE DRAIN BOX FOR VALVE ROD GLAND

Shoes are bronze castings, of wedge shape and adjusted by nuts against an end lug and having at the forward end stud bolts to clamp them to the head. They have large bearing area with oil grooves cast in the surface. The piston rod is held by screw and jam nut and in the piston by a straight forced fit and nut on the outside end.

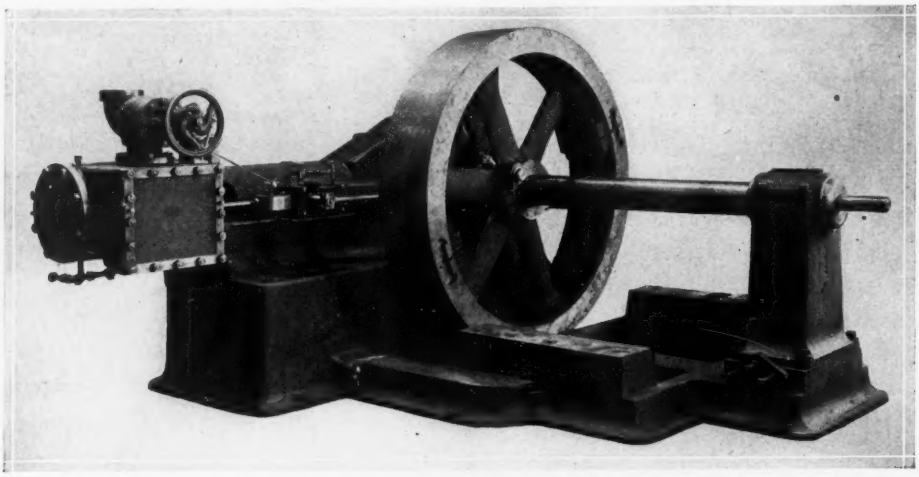


FIG. 3. VALVE GEAR SIDE OF BROWNELL ENGINE, SHOWING VALVE ROD GUIDE BAR AND ADJUSTMENT OF OUTBOARD BEARING

Flywheel, eccentric and Rites governor are split and removable, the governor being specially designed to bring the center of gravity close to the center of the shaft, to permit the use of a light spring, and with long inertia arms to give great sensitiveness to instantaneous change of load.

A forged steel valve rod guide bar is carried in brackets and runs in a flood of oil supplied from a pocket which is filled by the splash system.

The valve is of Sweet double ported type, but designed without center web to give lightness and freedom from casting strains.

It is covered by a flat plate which is held from endwise motion by adjusting screws so that the lead can be varied between the ends of the cylinder, a method which gives wide range in controlling the events of the stroke. The plate is held against the

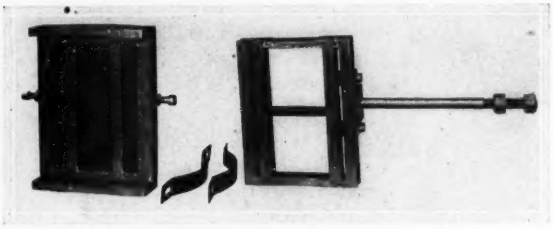


FIG. 4. VALVE AND PRESSURE PLATE, SHOWING RELIEF SPRINGS AND PLATE ADJUSTING SCREWS

valve by flat springs bearing on the steam chest cover, providing a means of relief in case of excess pressure.

The steam and exhaust ports are designed for low velocity, live steam flowing at not over 4500 ft. a minute and exhaust steam as low as 2000 ft. Under the cylinder of larger engines is placed a foot to carry the overhang and the weight of pipe and valves.

This Company also builds the same type of engine with high and low pressure cylinders, either the tandem or cross-compound type, condensing or non-condensing.

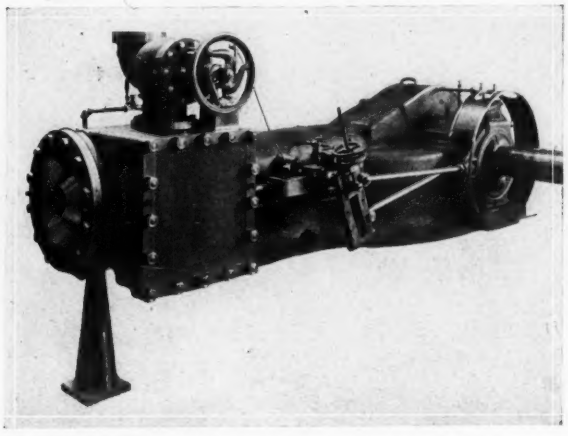


FIG. 5. BROWNELL ENGINE WITH VARIABLE SPEED LINK MOTION AND SUPPORTING FOOT FOR CYLINDER

In addition to the enclosed type frame, new designs have just been completed for an open type frame to be used in connection with either throttling or automatic governors. This open type frame will be built with on the smallest sizes. The open frame is the same as the quarter box bearing on the larger sizes and angle box rolling mill type of Corliss engine frame, and carries an oil pan under the crank to prevent oil reaching the foundation.

For use on mine fans and for other loads where variable speeds are needed, a form of Stephenson link is used, but with both eccentrics set ahead of the crank, one of them being 129 deg. ahead, and the other 191 deg. ahead, so that the travel of the valve is changed by hand by setting the link to bring the valve under control of one eccentric or the other.

The details of this fan engine are the same as for the automatic; Fig. 5 shows the arrangement of the link and eccentrics, and the form of cylinder head used in all engines.

CHANDLER AND TAYLOR ENGINES

Chandler & Taylor Co., Indianapolis, Ind.

ALL these engines are built to gage on the interchangeable plan so that repairs can be easily obtained. In many respects they conform to the best of usual standards such as the use of the Sweet multi-ported valve, the Armstrong governor, bored guides, box piston with snap rings, piston rod held into cross-

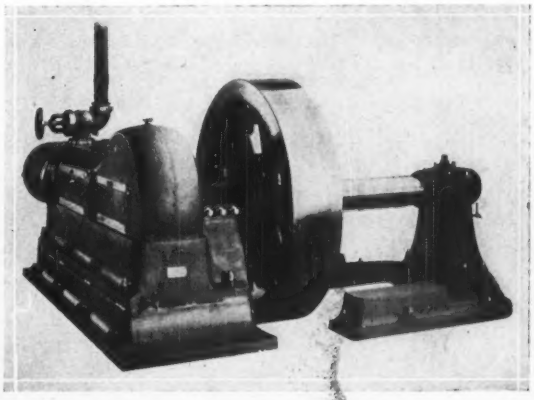


FIG. 2. ELECTRIC LIGHT ENGINE WITH SHAFT GOVERNOR AND SPLASH LUBRICATION

head with screw and jam nut, and double head to prevent condensation from the cylinder mixing with the oil. In many other parts special features have been adopted as the result of careful consideration of the requirements of the engine room.

For instance, every adjustment that has to be made is arranged to work by a fine thread screw, which can be easily reached, giving accuracy and convenience.

The frame is cast in a single piece extending from main bearing to cylinder, with long, straight lines giving strength, rigidity and pleasing appearance. This has large side openings as shown in Fig. 1 to give access to crank and crosshead, the crank cover being also removable.

The cylinder is bolted to the frame with a male and female joint, and in the larger sizes, above 100 kw., the back end is carried on a saddle with screws to adjust the height and side screws which permit of come and go with expansion, but prevent side swing.

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This saddle guards against any possible slight sagging of the cylinder from carrying on it too great weight of piping, valves and separator.

The 3-part quarter box main bearing has a shallow bottom piece resting on a flat base, and side pieces which extend over the top of the shaft nearly to meeting. The inner one rests against a space block, and the outer is adjusted by 3 screws through the frame,

Solid ends of the connecting rod are provided with bronze boxes for the crosshead end and brass, babbitted boxes for the crankpin, both having wedge adjustment in the same direction.

Adjustment of the box section crosshead is by shoes, wedge-shaped on the inner side and bearing against similar wedges on the head. Stud bolts in the end of the head carry double lock nuts bearing

FIG. 3. FANTAIL CRANK WITH SPLASH RIM

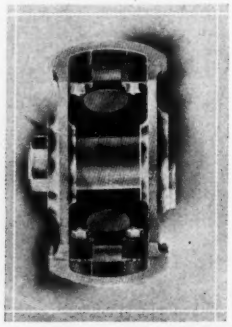


FIG. 4. DETAIL OF CROSSHEAD SHOE FASTENING

FIG. 5. ENCLOSED VALVE SLIDE

having locknuts to hold the adjustment. The cap extends over the jaws and is bolted down upon the side pieces, holding them in place.

The outboard bearing has a 2-part box spaced by shims, held together by bolts, supported on either side, as shown in Fig. 2, and held down by a screw through the cap.

The massively proportioned shaft has the semi-steel crank wheel forced on, the crankpin being cast

against lugs on the ends of the shoes to control the adjustment, and when in position, studbolts from the shoes are bolted through lugs on the inside of the head, clamping the shoes solidly in position. The pin has tapered ends, is held in position by a clamp nut and kept from turning by a key, but may be turned 90 deg. to equalize wear.

Stuffing boxes for both valve and piston rods are made with a single nut to draw up the packing, giving

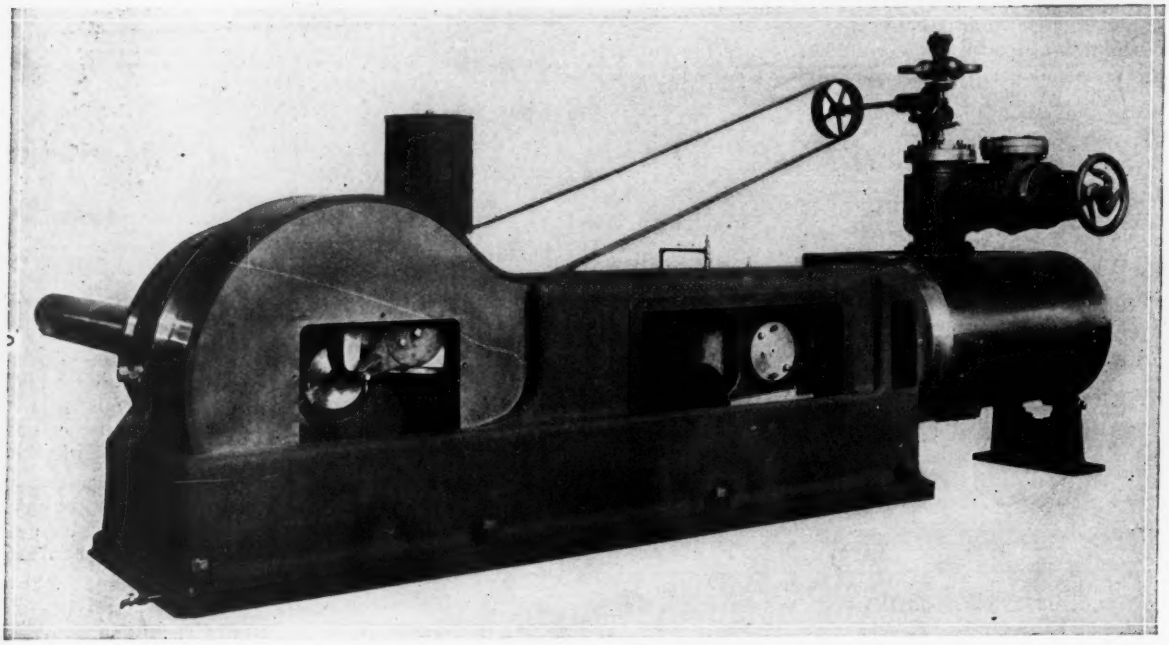


FIG. 1. 400-HP. CHANDLER AND TAYLOR ENGINE, WITH THROTTLING SPRING GOVERNOR, GRAVITY OILING SYSTEM AND OIL PUMP

solid with the wheel. This wheel is a fantail crank, giving the best of counterbalancing, but with a rim carried around over the pin and joined by spokes to give continuous dipping into the oil for splash system lubrication.

equal pressure at all points and can be used with either fibrous or metallic packing.

The heavy valve rod slide runs iron to iron in a bath of oil at all times, the valve rod passing through a driving pin and being adjustable by lock nuts on

either side. On the other end of this pin the eccentric rod turns, with a ball and socket joint.

Ball and socket joints are used at all governor and eccentric connections allowing sufficient side play so that the gear takes its natural position and avoids

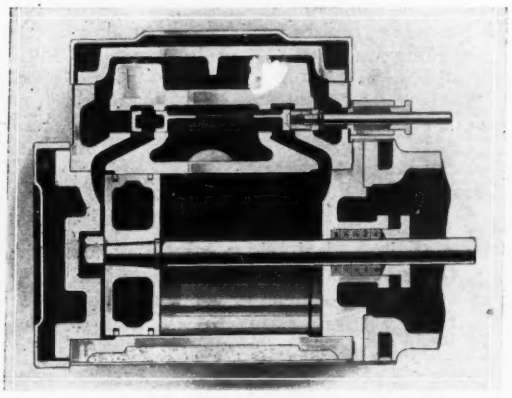


FIG. 6. SECTION OF CHANDLER AND TAYLOR CYLINDER AND STEAM CHEST

side binding. The split eccentric strap has a socket bearing on one side and adjusting nuts on the other so that wear can be taken up easily and by fine adjustment. Eccentric and flywheel are also split so that they may be removed without disturbing the shaft.

Either gravity-feed with a 2-compartment filter and return pump or splash lubrication is furnished as desired. When the splash system is used, all bearings are thus oiled except 2 connections on the governor link rod, which have grease cups. A slinger ring on the shaft takes oil from the end of the main bearing into the trough on the inside of the eccentric,

FIG. 7. ARMSTRONG GOVERNOR OF CHANDLER AND TAYLOR ENGINE WITH SPLIT ADJUSTABLE ECCENTRIC STRAP

whence it passes to the pivot pin and from the inside end of that through a drilled hole to the eccentric strap and flows from the eccentric case back to the crank case. Other bearings are flooded by the crank rim in the usual manner.

RUSSELL SINGLE-VALVE ENGINE

The Griscom-Russell Co., New York, N. Y.

THE Russell single-valve engine is specially designed for use in electric light and power plants, where close regulation and high economy are essential. The bed is of box section, of the enclosed type, with the principal running parts practically immersed in oil. It is well ribbed to resist internal strains, made extra heavy to absorb vibration due to high rotative speed, with heaviest sections in line with the greatest strains and so disposed as to give a pleasing sense of grace and strength. Openigs are provided which allow easy access to all working parts.

The main bearing has 3 parts, the adjustable side shells nearly encircling the shaft with full length adjusting wedges to maintain a perfectly round journal. The bottom shell is free to move endwise to adapt itself to any adjustment made to the side shells. These shells are lined with babbit, thoroughly pened in place,

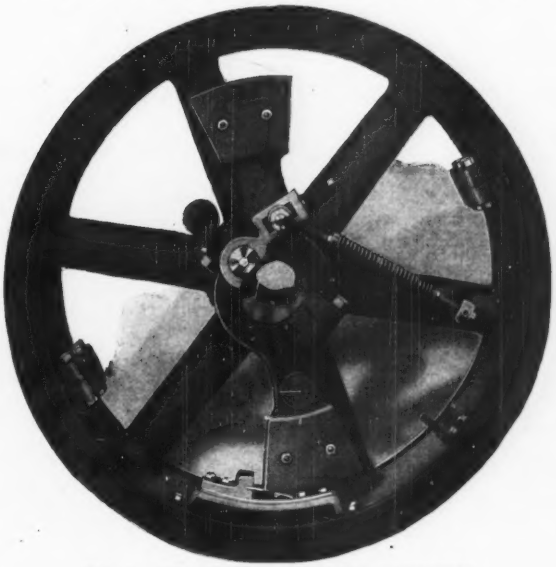


FIG. 2. THE RUSSELL INERTIA GOVERNOR

accurately bored and then scraped to a perfect surface. In removing the bearing, first take out the liner back of the front shell; then the shell itself. Next take out the taper liner and wedge from the opposite side, and the rear shell, and lastly by raising the shaft slightly the lower shell is removed without difficulty.

The valve is of the flat double-ported type and is held in balance in all positions between the cover plate and cylinder seat. It is driven through rods, rocker arm and eccentric strap lined with genuine babbit and lubricated either automatically from within the bed, or by an oil cup. The valve rod has a ball joint, to insure straight travel to the valve, and both valve and eccentric rods are adjustable for length by screw threads and nuts.

The crank shaft is turned from a solid forging and in direct connected service, the extension for receiving the armature or rotor is machined to micrometer measurement, proper allowance being made for press fit. Oil grooves are provided at the ends of bearings to prevent creeping of oil along the shaft. The crank disk is a steel casting, having forged steel pin pressed into place.

The forged steel connecting rod is solid at both ends, with crosshead pin box of phosphor bronze, and

crank-pin box of gun metal with antifriction metal lining, both boxes having wedge block adjustment.

The substantial crosshead body is of annealed cast steel, provided top and bottom with adjustable babbit faced shoes of the cylindrical type, and ground crosshead pin of hardened steel. Provision is made for turning the pin as it wears.

The piston is a single, strongly ribbed, hollow casting, made as light as is consistent with strength. It is packed with cast-iron snap rings, between which is put a band of antifriction metal to act as carrier of the weight of the piston. The band expands just enough more than the iron to prevent the piston coming in contact with the cylinder walls, thus rendering impossible any cutting or scoring thereof.

The large diameter piston rod is made of special piston rod steel, and joined to the piston by a taper fit and jamb nut. The rod screws into the crosshead with a long fine thread held by heavy jam nut, which is locked by a set screw in the crosshead body.

The splash system of lubrication is furnished with style 4 engines, as illustrated. With smaller and medium size engines the bed is mounted on an extra heavy cast-iron sub-base, with extensions for support of generator and outboard bearing. With engines of the largest size, the bed is designed to rest directly on the foundation and the sub-base is unnecessary.

Single valve engines are built either simple, tandem or cross-compound, for belt drive or direct connection and in all commercial sizes.

FLEMING-HARRISBURG SINGLE-VALVE ENGINES

Harrisburg Foundry and Machine Works, Harrisburg, Pa.

IN these engines, designed particularly for hard service, the sidecrank design gives 2 bearings which can easily be kept alined. By boring the guides and facing the end of the frame to which the cylinder is attached at one setting, guides and cylinder are brought square, and liberal allowance of metal insures strength and rigidity to prevent springing. Quarter boxes are used for main bearings and outboard, the 4-part liners being accurately machined on all sides, with antifriction metal hammered into place, then carefully bored and scraped. Adjustment is by means of heavy screws with locknuts seen on the side of the main bearing in the general view of the engine.

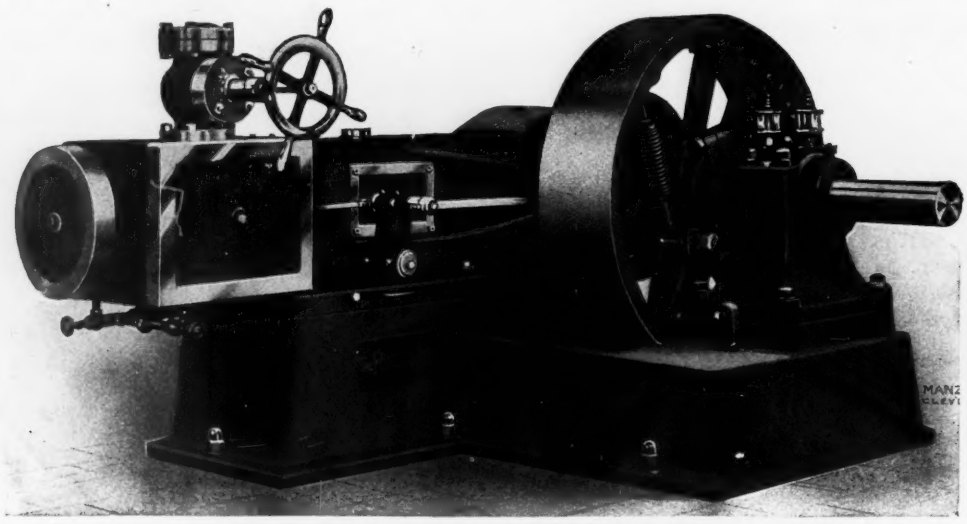


FIG. 1. REAR VIEW OF RUSSELL SINGLE-VALVE ENGINE

The cylinder, cast from a special close grained and extremely hard iron, has the barrel covered by a heavy jacket, with the intervening space filled with nonconducting material. Over the cylinder head and nuts is placed a false head, having a polished outer ring and center.

The inertia bar governor may be adjusted for whatever speed or direction of rotation is desired. Speed is increased by increasing the tension on the spring or by adding weight to the long end of the weight arm. speed is reduced by decreasing the tension of the spring or by adding weight to the short end of the arm. The spring tension is adjusted by a block to which one end is fastened, sliding in a slot in the inertia bar under control of a set screw.

The fulcrum pin carrying the weight arm, should be kept well oiled and occasionally treated to a good bath of kerosene oil to cut any dirt or grit that may have collected.

The outboard bearing is in perfect harmony with the proportions of the bed, having a broad base, with heavy sections of metal in all parts. Horizontal adjustments are made by set screws in lugs on the pedestal sub-base; vertical adjustments by placing liners under the pedestal.

Where the weight and length of cylinder warrant, the cast-iron sub-base to support the frame is extended to carry the cylinder and prevent sagging. Cylinders provided with metal to permit safe reboring, are rigidly fastened to the frame by stud bolts through a heavy flange.

The piston is made light but strong with piston rings of the L or steam-packed type, having a square joint covered with a brass plate. These rings are sprung into accurately fitted grooves in the piston, the lower portion fitting snugly, while a space is provided at the upper side to admit steam under the overhanging part. This presses the ring against the inner side of the groove in the piston, as well as against the cylinder wall, making an effective and lasting steam-tight joint.

Pistons 26 in. in diameter and larger have a bull ring of phosphor-bronze, adjustable by set screws, to maintain alinement of the rod. The rod is turned taper at the piston end and driven home to a shoulder, where it is securely held by a heavy nut, which is drilled and cottered.

The crosshead has shoes of phosphor-bronze firmly bolted directly to the crosshead, and finished after attachment, thus insuring alinement. The wristpin is taper at the same angle toward both ends, and security fastened by means of locknuts; it is flattened top and bottom, to prevent the wearing shoulders and facilitate lubrication.

The solid forged rod has ends slotted for crosshead brasses, bearing boxes, which are steel castings heavily lined with the best babbitt.

The main supply of oil is concentrated in the crankpit, with a sight glass to show the quantity of oil present. The crank-disk is constantly in contact with this oil, and carries up a film of oil which centrifugal force throws back upon the crosshead and guides, also into a trough, placed across the inside face of the oil hood, from which a tube conveys this oil to a point over the main bearing, to which it flows in a constant stream, always visible to the attendant. This oil also finds free access to an annular eccentric groove cut in the face of the crank-disk next to the bearing, giving in effect a centrifugal pumping system that is unfailing in effectiveness and entirely automatic.

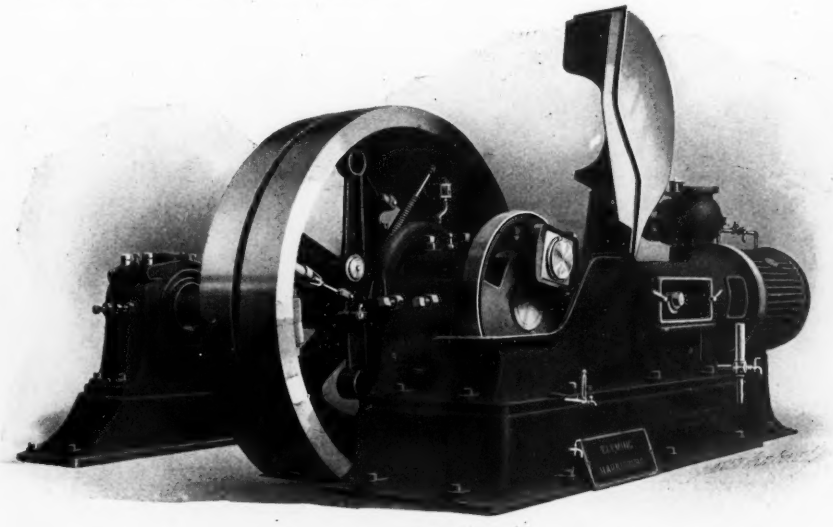


FIG. 1. HEAVY DUTY FLEMING HARRISBURG SIDE CRANK ENGINE

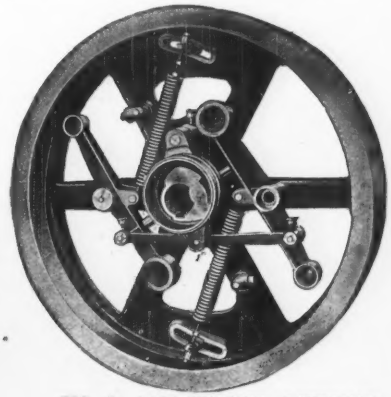


FIG. 2. THE FLEMING GOVERNOR AND FLYWHEEL

FIG. 3. FLEMING-HARRISBURG PISTON TYPE VALVE

Crank disk and crankpin are of steel cast integral, the pin of much larger diameter than could be employed if made separately and forced into the disk. The pin serves as a substantial reinforcement to the disk, which is securely fitted to the crankshaft besides being keyed to it, and is proportioned to counteract the inertia of the reciprocating parts.

The centrally-balanced, centrifugal-inertia governor has 2 lever arms with end pockets for detachable governor weights, and controlling springs. Perfect balance avoids "slamming" in starting and stopping, and sensitive response to the slightest change in speed is insured by using roller-bearings, with pins hardened and ground and the links bronze-bushed. Change of speed is accomplished by placing different weights in the pockets, and by varying the tension of the springs.

The eccentric is strong but light, with ample bearing surface to insure long life, and the strap shows similar characteristics. Connection between strap and valve stem is by a rod, pin and slide or ram of circular form. The ram-pin is of phosphor-bronze lined with babbit, and with means for taking up all wear.

The piston type valve has heads separate and adjustable relatively to each other, by means of bronze locknuts to get the most effective steam distribution to meet varying requirements. The valve operates in cages, which permits of inexpensive repairs and dimensions of all valves and bushings are kept on file so that renewals may be promptly furnished.

To relieve dangerous pressure from water or other cause there are fitted on the smaller engines an explosion diaphragm at each end of the cylinder, consisting of a cast-iron disk, which will give way when pressure rises approximately 50 per cent above initial steam pressure. Where diaphragm of larger diameter than practicable is necessary, shifting or pop valves are used for the same purpose.

THE IDEAL SIDE CRANK ENGINE

A. L. Ide & Sons, Springfield, Ill.

FAST moving machines require strength and rigidity of the frame work, which is met by a cross-section of great depth, with the housing of frame carried entirely around the main bearing to take care of the thrust from the overhanging crank.

The main shaft bearing is extended toward the center line of the engine, reducing the overhang to a minimum and bringing the thrust of the connecting rod close to the bearing. Checking of alinement is by means of 3 faced bosses cast on the inside of frame at the crank end. A pointer or gage is screwed into a tapped hole in the counterweight or crank, and by turning the crank the pointer can be brought opposite each projection, and the distance measured, care being taken to eliminate the effect of end play.

The main bearing has removable shells, the bottom shell having a circular seat so as to fix the aline-

ment of the shaft, and permit the shell to be removed by jacking up the shaft a few thousandths of an inch. Both side shells are adjustable, with separate wedges for each end so that the more rapid wear next to the crank disk can be followed up without pinching at the

Pedestal and shaft bearing for supporting the end of the crank shaft have a flaring base with sufficient support upon the foundation, to insure rigidity and stability. The bearing for the shaft is a split cast-iron sleeve, turned to seat properly in the bored housing,

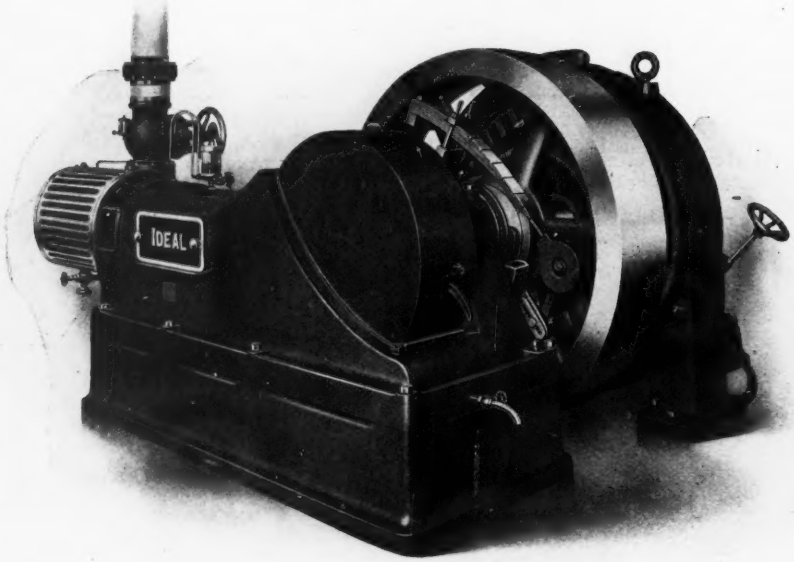


FIG. 1. FRONT VIEW OF IDEAL SIDE CRANK ENGINE

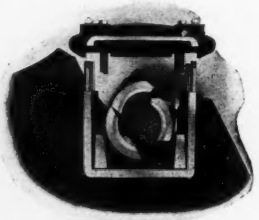


FIG. 2. MAIN BEARING PARTLY DISASSEMEBLED

other end of the bearing. The main bearing is accessible through the cap for examination, and is kept submerged in oil.

The hood over the crank-case which forms an oil-tight enclosure can be turned back on a support to permit inspection of crank and connecting-rod; or can be entirely removed to permit adjustment of working parts.

Open hearth steel crank-shaft, crank-pin and arm, are formed of one piece. The main shaft is of the coupled type with separate extension for the reception of pulley, or direct driven machine. The shaft and extension have solid flanges that will enter the re-

and lined with babbit. The housing around the sleeve forms an oil-tight casing, with oil basin cast under the bearing, and sight glass. Metal oil rings revolve with the shaft and carry oil from basin to top of shaft.

Attachment of the cylinder to the frame is by pockets cast in to receive the nuts on the studs. Double stuffing-boxes are provided, visible and accessible through large handholes in each side of the frame, with chamber to prevent the mixing of drip from the stuffing-box with the oil in the crank-case.

The piston is cast hollow and light, with rod tapered and shouldered, and the head forced on the rod under hydraulic pressure, and there secured by a nut

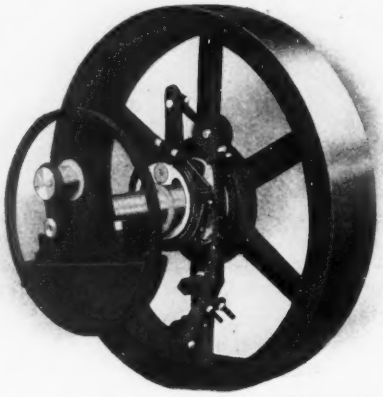


FIG. 3. FLYWHEEL WITH GOVERNOR, ECCENTRIC AND CRANKSHAFT

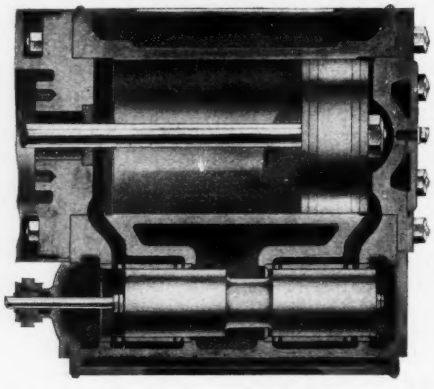


FIG. 4. SECTION OF CYLINDER AND STEAM CHEST

cessed hub of the flywheel and be locked by bolts passing through both flanges and the hub. Two of the through-bolts pass through the bracketed end of the eccentric pin and secure it to the flange of the shaft.

which is locked by a threaded plug. The rectangular box crosshead, reinforced to increase its strength, has wearing surfaces of the shoes of bronze, rendering them durable and decreasing the necessity for continued adjustment, which when necessary is only on

the lower slide. By bolts and a series of holes the wristpin can be revolved to present a new bearing surface to the points of greatest wear. The forged, one-piece connecting-rod has ends being bored out to receive the boxes, which in the crank end, are of finished cast steel lined with babbit, and on the crosshead end are of bronze. Taper cylindrical wedges, located in bored and fitted recesses in the ends of the rods, provide means for taking up wear, with the wedges well seated by the contact of the finished cylindrical and flat tapered surfaces. These wedges placed on the same side of both boxes, prevent change in the length of the connecting-rod and are firmly locked by cap screws. The boxes have the sliding surfaces horizontal and tangent to the inside wearing surface of the boxes at point of intersection of the 2 boxes, with the result that the boxes fit snugly around the pins.

In the Armstrong governor, a powerful spring is used to resist the centrifugal force of the weight, which is mounted on the end of the spring, thereby removing pressure from the governor bearings. Motion of the governor swings the eccentric across the shaft, thus changing the valve travel as load changes.

The eccentric strap is made in 2 parts with babbit shells which are easily removed and replaced, and have the contact surfaces with the eccentric shaped to the arc of a circle to prevent lateral motion. A micrometer sleeve is provided for adjusting the strap to take up wear. The eccentric rod is pivoted to the eccentric with sufficient swing to permit quick alinement with the pin bearing at the opposite end, which has a split bronze bushing with adjusting screw and lock nut.

The light valve is of piston type, with long wearing surfaces, and runs in bushings which can be bored and reamed to receive a new valve of slightly larger diameter, when long wear makes such replacement desirable.

Lubrication is from dynamo oil in the reservoir under the crank, into which the latter dips. The revolving crank sprays the oil generously on the surfaces of the crosshead guides and slides, and also into pockets provided for its reception on the hood; from these pockets it is delivered by gravity and centrifugal force to the crank-pin, and by gravity to the pockets on the main bearing sleeves and to the other parts of the engine which are to be automatically lubricated.

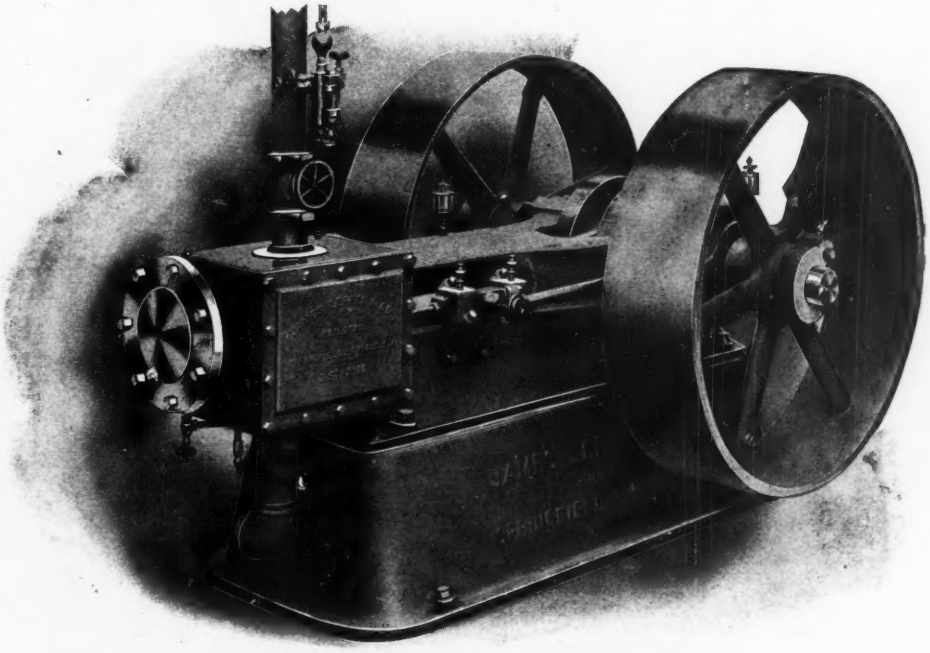
Lubrication of the eccentric is accomplished by feeding oil to a grooved collar on the shaft and from there distributing it by centrifugal force to the pin bearing and to the bearing surfaces of the eccentric and strap.

LEFFEL ENGINES

James Leffel & Co., Springfield, Ohio

TWO classes, A and B, are manufactured, both center crank with single balance valve. The main details are the same except that class A has throttling governor and fixed eccentric, while class B has automatic shaft governor.

The frame is stiff and strong, of Y design with girder section, carrying the cylinder and steam chest firmly bolted to the end. The main bearings are carried on the frame with caps set diagonal and adjustable for wear. The hollow piston carries snap rings and is forced onto the rod which is riveted over. Adjustable slippers top and bottom, running in bored guides, provide for taking up crosshead wear, and the pin with tapered ends, and locknut provides for taking up wear and turning the pin to avoid wearing flat. The connecting rod has a solid end at the crosshead and strap end at the crankpin, of generous proportions. The valve is of the Sweet type, multiported and balanced with pressure relieving plate on the back. The governor is the Rites improved with one spring and arm carried on a hardened steel pin in a bronze bushed hole, and changing the valve travel. Motion is carried through the eccentric strap, rod and slide to the valve rod. Class A engines are built in sizes from 5 by 6 up to 10½ by 12 in., and Class B from 7 by 10 up to 10½ by 12 in.



THE LEFFEL CLASS B ENGINE WITH IRON SUB-BASE

RIDGWAY SIDE CRANK ENGINE

Ridgway Dynamo and Engine Co., Ridgway, Pa.

PLEASING outlines, and heavy design throughout, with the metal distributed to bring the heaviest sections in line with the greatest strains, are characteristic of the bed which is of box section with bored guides of large diameter. In the bed a removable partition, with sectional packing around the piston rod, prevents oil from being thrown against the end

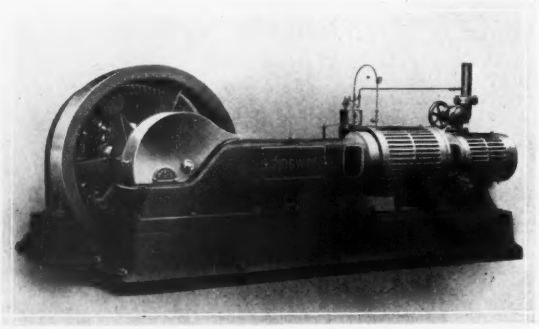


FIG. 1. RIDGWAY TANDEM COMPOUND ENGINE

of the cylinder. At the crank end of the lower guide, a well cast in the bed receives all oil and drip, the water settling to the bottom and being carried to an outlet at the side of the bed, while the oil overflows to the crank case to be used again. A sheet steel guard, hinged to be turned back over the bed, covers the crank disk, with a small opening having swinging cover at the side to allow inspection of the crank-pin while running.

For the largest engines, the bed is designed to rest direct on the foundations, for medium size, a sub-base is provided, extended to support the cylinder, while for sizes under 100 hp. the cylinder support is omitted.

FIG. 2. CROSSHEAD SHOWING LOWER SHOE ADJUSTMENT

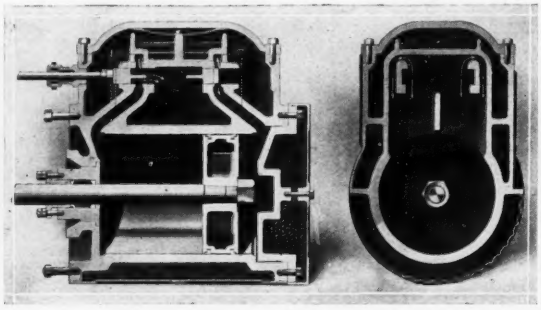


FIG. 3. HORIZONTAL SECTION OF CYLINDER AND VALVE, AND VERTICAL SECTION THROUGH THE HEAD END PORT

The main bearing, of quarter-box type, has shells lined with babbit, top and bottom shells being interchangeable, and all shells easily removed without taking the shaft out of the bed. Horizontal adjustment is secured by a wedge and vertical adjustment by drawing down the cap while the engine is in operation.

The upper crosshead shoe is bolted solid to the body, while the lower shoe is adjustable by 4 hollow screws, without heads, located inside of the 4 lugs on the body. Each screw is turned by a blank nut, on which are 2 projections corresponding to slots cut in the top of the screw. By turning the nut, which acts as a screw driver, the screw forces the shoe and body apart or allows them to come together. A stud in the shoe passes through the screw and nut, and a nut on the stud holds the shoe securely. A heavy lug extending entirely across the back of the shoe, projects into a recess in the body, to hold the shoe central and prevents it from being stripped.

FIG. 4. RIDGWAY GOVERNOR WITH INERTIA BAR, ECCENTRIC BALANCING WEIGHT AND DASHPOT

Connecting rod ends are slotted out of the solid forging, the crosshead pin box being of solid phosphor bronze, while the crankpin box is of bronze lined with babbit. Wedges and bolt adjustment at each end is so located as to not change the centers.

The valve consists of an open rectangular casting, which works between the valve seat and a pressure

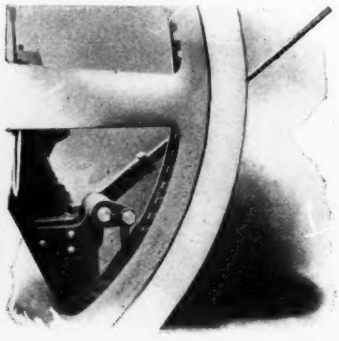


FIG. 5. RIDGWAY DEVICE FOR TURNING OVER ENGINE

plate relieving the valve of all steam pressure, and affording a passage from the steam chest to the cylinder past the valve in 2 directions, producing equal pressure in opposite directions over every portion of the valve. The pressure plate is fitted on pins which prevent lateral motion, and is held to its seat by a spring on the back, so that both valve and pressure plate will lift to allow water to pass directly into the exhaust.

In the governor, a long inertia bar, with weights at each end, is pivoted at the center on a large main pin and the space between the pin and a single long

bushing being filled with rollers. To the hub of this bearing is clamped and keyed the split eccentric, with split eccentric strap, so that eccentric and strap may be removed without disturbing governor or setting of valves. Directly opposite the eccentric is a third weight, which balances the effect of gravity on the eccentric, and equalizes the strains on the roller bearing. A heavy coil spring is attached to the middle of one end of the inertia bar, and an oil dashpot to the other end, having a bypass with adjustable opening to allow the oil to circulate from one side of the piston to the other, so that the sensitiveness of the governor may be changed.

If the weight in the inertia bar and the tension of the spring are so adjusted that the centrifugal force increases faster than the tension of the spring, the engine will speed up under load. In this condition the engine is liable to race and it is to prevent racing that the dashpot is used. No difficulty is experienced in adjusting this engine to govern within a limit of one revolution and the instantaneous variation of speed when full load is thrown on or off is less than 2 per cent, the engine returning to its normal speed with a single vibration and within 2 to 4 revolutions.

The piston, a single hollow casting, is packed with cast-iron snap rings. For pistons 16 in. diameter and over, a special design which makes the interior accessible for inspection, avoids the use of chaplets and plugs, and prevents the occurrence of shrinkage strains. Rings of antifriction metal are placed in the rim to bear the weight of the piston.

The main shaft is a single semisteel forging, large in the bearings and in the governor wheel hub. The large crankpin is cast solid with a disk, so shaped as to give great strength and counterbalance. On the inside of the bed, opposite the main bearing, are surfaces machined true with the center line of the bed. If the distance between these surfaces and the disk calipers the same after the shaft has been turned 180 deg. as it did before, then the shaft is in line, if both shaft and bed are level.

The valve is driven through rods and a large ram which has a long bearing in the guide. Both horizontal and vertical adjustments are provided.

A special feature of the engine is the ratchet turning over device, shown in Fig. 5, by which one man can turn the largest engine off center with ease. When not in use the device turns backward out of the way of the governor wheel or any moving part.

Two methods of lubrication are provided; the first by the splash system, from the crank pit; second, the standard system consists of a tank mounted on the sub-base below the valve gear, and containing a filter and a small pump. All oil from the bearings flows to the crank pit, from which it is piped to the filter and is then pumped to a stand pipe provided with an overflow. From the stand pipe the oil is conducted to the various bearings, at which points the amount of oil flowing may be observed. When desired, the valve in the outlet from the bed may be closed and lubrication will automatically begin by the splash system.

This engine is built in the simple, tandem-compound, and cross-compound types. On tandem engines, both valves are driven by the governor, the low-pressure directly and the high-pressure by means of a tail rod on the low-pressure valve. On cross-compound engines the high-pressure valve is driven by the governor and the low-pressure by a fixed eccentric on the main shaft; otherwise the gear is identical for each cylinder.

RIDGWAY ADJUSTABLE CUTOFF ENGINE

Ridgway Dynamo and Engine Company, Ridgway, Pa.

FRAME, shaft and other details are the same as for the standard Ridgway engines. The adjustable cutoff is used for loads such as mine fans which are constant at a given speed, but must be varied by varying the speed to meet the requirements.

A slotted link is pivoted at its upper end on a large steel shaft supported by a casting bolted to the bed. The link is securely held by set screws to the shaft which works in a split bronze bushing in the supporting casting and, as this bearing is very long, the wear is negligible. Near the center of the link is a yoke connection for the eccentric rod. In the slot is placed a large, tight-fitting bronze block, with one grooved side, which carries a steel pin passing through an extension of the eccentric strap. On the upper side of the block is a connection for a vertical screw,

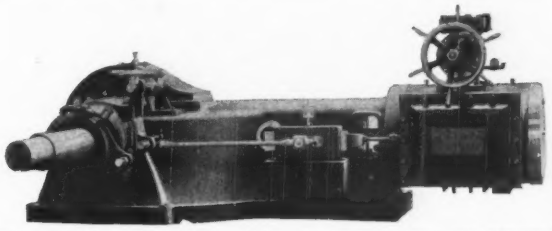


FIG. 1. RIDGWAY SIDE CRANK ENGINE WITH ADJUSTABLE CUTOFF

which passes through the end of the supporting shaft, and carries a large hand wheel with a specially shaped hub, fitting into slots in the shaft, preventing vertical motion of the wheel. On top of the hand wheel is a small star wheel acting as a lock nut. Since both block and link are suspended from the same center, they move together except when the hand wheel is being moved to change the point of cutoff. The application of this gear to a center crank engine is practically the same, motion being taken from a pin in the end of the shaft through a link as described.

SKINNER AUTOMATIC ENGINES

Skinner Engine Co., Erie, Pa.

BOTH center crank and side crank engines are built by this company, all having the 3 features of frictionless governor, steam tight valve and automatic lubrication.

To render every part of the engine accessible, the walls of the bed, which surround the operating mechanism, have the top open and covered with light nickel-plated oil shields.

The bed is machined at one setting on a special tool, and afterwards all parts are brought to perfect alinement by scraping to surface plates. Upon these true surfaces are mounted the guides, main bearings and stuffing boxes, which have also been perfected in the same manner, giving a variation from perfect alinement of not over 0.01 in. in the whole length of engine, and insuring quiet and cool running under all conditions of load.

To prevent the cylinder oil from mixing with the engine oil, and the engine oil from splashing against the hot head of the engine, and to prevent condensation containing alkali reaching the engine oil, a bulkhead partition is used as seen in Fig. 2, with stuffing

box containing metallic packing which will last for years, but can be renewed without dismantling any part of the engine.

The upper half of the bulkhead can be removed from the engine frame while in operation, and the entire bulkhead, including the metallic packing, can be taken from the frame simply by removing 2 cap screws.

The 4-piece main bearing has bottom and top free to move with the shaft when adjustment of the quarter

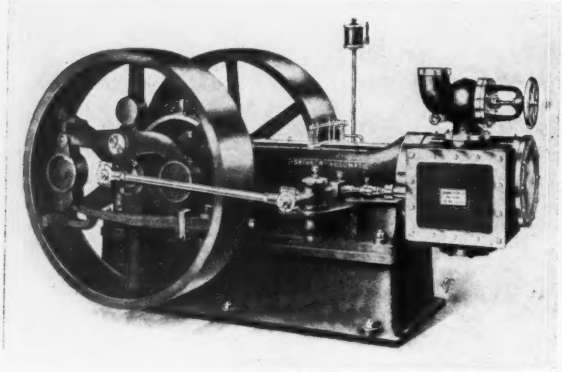


FIG. 1. SKINNER AUTOMATIC CENTER CRANK ENGINE

box is made, thus keeping every part of the box in contact with the shaft. By the use of adjusting screws, proper contact can be made and determined by sense of feeling, when the engine is in motion. By removing the weight of shaft from the lower box, every part of the bearing can be removed and duplicates substituted, because of perfect alinement, already described. The heavy bearing castings are rigidly held in place by screws reaching through the cover and adjusted from the outside, making practically a solid box.

with iron box lined with babbitt at the crank end and a bronze box at the crosshead end, and on sizes 12 by 15 in. and above, steel crosskeys recessed into the straps and the stub ends of rod take any unusual strain. Adjustment is by a set screw attached to a wedge key, by means of which the wedge, bearing the full width of the box, is lifted or lowered. Slotted clips, secured to sides of wedges and strap, prevent any possible vertical movement of wedges, and as the wedges and set screws are accurately fitted, no lost motion is possible.

The heavy crank web has counterbalance weights, attached by mortise and through bolts, giving accurate running balance and room to adjust connecting rod boxes.

By mounting the entire governor system on a roller bearing, inertia and centrifugal forces are so placed in opposition to the spring as to admit of the elimination of all friction without affecting stability. The governor mechanism consists of a weighted eccentric arm, a link and a leaf spring. The weighted link connects the arm and spring by hardened frictionless bearings; the tension of the spring is always in one direction, preventing lost motion and noise, requiring no adjustment and scarcely any lubrication.

To increase speed, remove weights; to reduce speed, add weights; to reverse the motion of engine, the mechanism is simply reversed in the wheel. A spherical wrist pin on the eccentric arm connects as shown, to a rod and horizontal rocker which drives the valve rod through a ball joint.

Eighty per cent of the valve area is relieved of pressure by a balance ring which rides against the steam chest cover, and is free to revolve with every stroke of the valve, preventing cutting of seat, ring or cover. Steam packing rings prevent leakage between the ring and hub, and coiled springs maintain contact between the balance ring and cover. This construction allows large port area to give development of

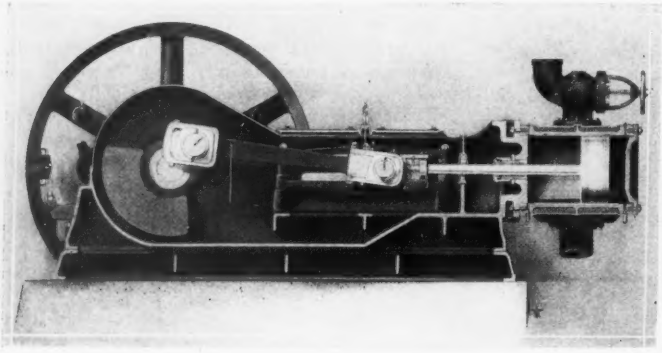


FIG. 2. VERTICAL SECTION OF SKINNER SIMPLE ENGINE

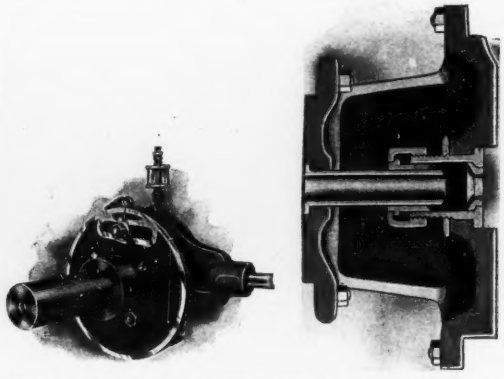


FIG. 6. ADUSTABLE LOW-PRESSURE ECCENTRIC, AND DISTANCE HEAD FOR TANDEM-COMPOUND ENGINE

The ring-oiled outer bearing acts simply as a steady rest, and is carried on a block, vertically adjusted by set screws from the bottom, and horizontally by screws on the side of the housing.

The crosshead is purposely made heavy, of rectangular form, with large wearing surface and with a wristpin diameter ⅔ that of the crankpin.

Skinner engine guides are of locomotive type, adjustable top and bottom and entirely removable from the engine frame. They are scraped to a true plane, and after years of wear can be brought back to their original condition.

The heavy forged-steel connecting rod is fitted

the full cylinder power, while leaving the valve free to lift from the seat if water enters the cylinder.

For excessive or widely fluctuating pressure, or for superheated steam, a flat balanced expanding valve is used, made in halves, projections A on one part interlocking and forming steam-tight joints with projections B on the other half. Steam enters at point C between the halves, pressing one against the valve seat on the cylinder and the other against the seat on the steam chest cover. The pressure on the ends of the valve holds the halves in steam-tight contact with each other at the joints between A and B, and closure strips seal the valve at top and bottom.

In both center crank and side crank compound engines an independent eccentric is employed to operate the low-pressure valve. This eccentric can be shifted so as to vary the cutoff and equalize the load between the 2 cylinders, after the average load has been once determined. It is so designed that in shifting for the various points of cutoff the valve travel is equalized and requires no other adjustment.

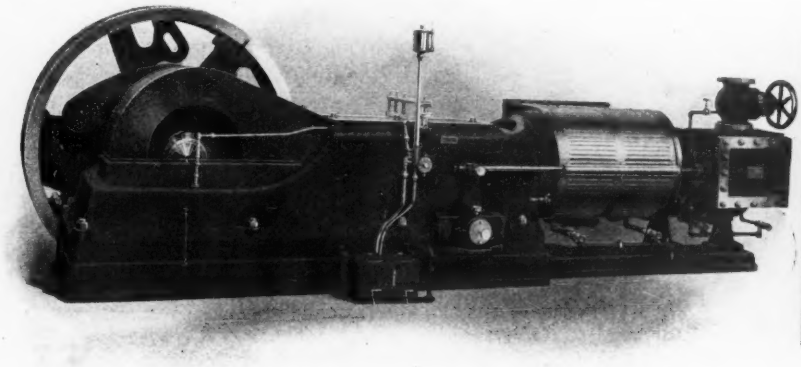


FIG. 3. SKINNER TANDEM-COMPOUND SIDE CRANK ENGINE

The builders claim that by the adoption of the independent eccentric they are enabled to eliminate considerable clearance in the low-pressure cylinder, and divide the load or the temperature range more equally between the 2 cylinders than can be accomplished where both valves are driven by the governor eccentric.

Connecting the 2 cylinders is the distance head with but one stuffing box, at the low-pressure end,

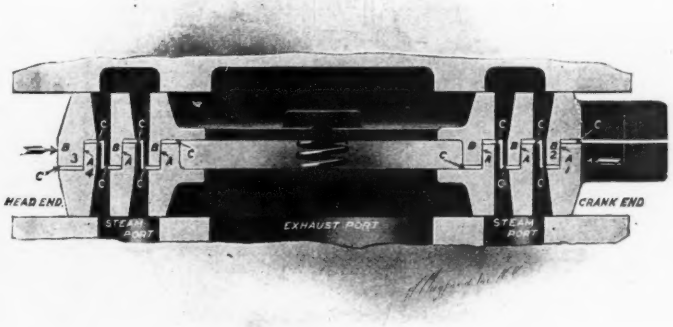


FIG. 5. HORIZONTAL SECTION OF FLAT EXPANDING VALVE AND SEAT, AND HALVES OF VALVE SEPARATED

and a bronze sleeve, making a long supporting bearing for the piston rod and protecting it from the atmosphere. By this arrangement the box packs only against the difference in pressures between the 2 cylinders, and the cylinders can be placed close together, giving a short receiver connection.

In the Skinner lubrication system oil flows from the bearings into the bottom of the bed, then through 28 ft. of filter to a settling tank and is raised by the oscillating pump to the adjustable feeder and overhead tank. The feeder which stands crosswise of the bed, Fig. 1, is hinged with a shutoff valve in the hinge so that when shutting down, the feeder is raised and all flow of oil stopped; before starting, the feeder is lowered and oil from the tank flows into the system to wet the bearings.

The inner 2 sight feeds supply guides, and crosshead, and the outer 2 feed canals in the top of the bed which supply the main bearings, and the crank-pin box.

In the side crank engine, the same governor,

FIG. 4. RING BALANCED VALVE WITH PARTS SEPARATED

valves, lubrication system and general features are used as in the center crank. The frame is of one bearing construction with extended sub-base and outboard pedestal. The crank has a quadrant extension opposite the pin which is cored out and filled with

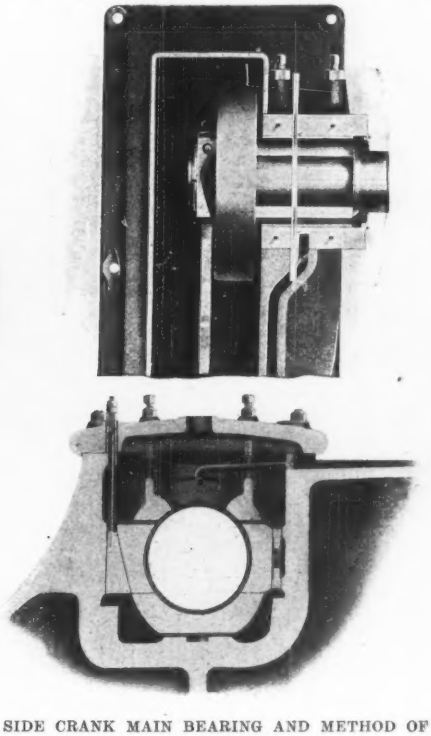


FIG. 7. SIDE CRANK MAIN BEARING AND METHOD OF LINING UP SHAFT

lead to give proper counterbalance, and a steel crank-pin pressed in and riveted over. At the crank end, the connecting rod is cut from a solid forging and has iron, babbitt-lined boxes with wedge and screw adjustment.

A 4-part main bearing is used similar to the one for the center crank, but with 2 special features; at the inner side is a distance block which can be removed, allowing the quarter box to be removed without shifting the shaft; and the outer quarter box is adjusted by a wedge operated by studs and nuts bearing on a projection of the main bed, so that adjustment is not disturbed by removing the cap.

For determining alinement of shaft, a straight edge is placed against pins located in the housing over the shaft, and brought exactly in line with the center line through the guides and cylinder. Measuring from the outer ends of the straight edge to the crank, the shaft is in proper line when both measurements are alike.

ACME AUTOMATIC ENGINE

Sterling Machine Co., Norwich, Conn.

THE Acme engine is of the single acting 2-cylinder type, with a pair of vertical cylinders above an enclosed crank case which serves as a rigid foundation for the engine as well as a reservoir for the oil used in the automatic splash system of lubrication.

The valve is of the oscillating type, a one-piece casting ground to fit an accurately bored chamber in the cylinder head, and so designed as to adjust itself automatically to take care of any wear which may develop, in the same manner as does the Corliss valve. Automatic relief valves are provided in the top of the cylinder head to release water which may collect in the cylinders.

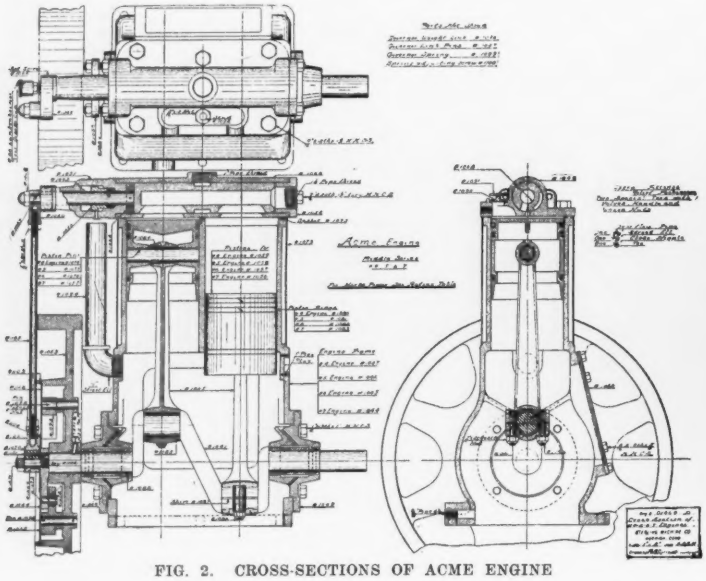


FIG. 2. CROSS-SECTIONS OF ACME ENGINE

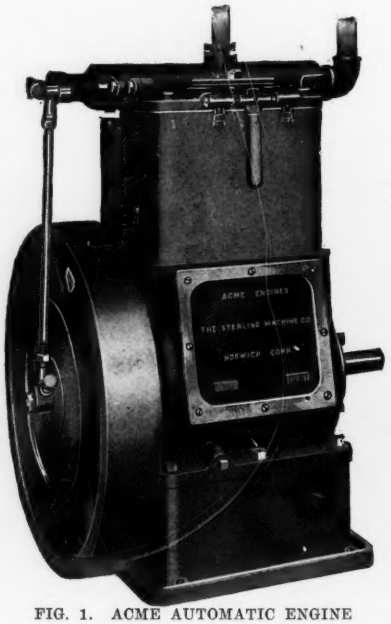


FIG. 1. ACME AUTOMATIC ENGINE

The main bearings are heavy castings bronze bushed, bolted to the crank case, and removable to take out the crank shaft. The bushings are interchangeable and when worn may be replaced with new ones at slight cost.

The connecting rods are of I-beam section, bronze bushed at both wrist-pin and crankpin ends.

The pistons are of trunk pattern, also acting as crossheads, with 3 piston rings, 2 above the wrist pin and 1 below. The wrist pin is hollow, hardened and accurately ground to size. The cylinders are counterbored at the top, making it impossible for the rings to wear a shoulder.

The governor consists of 4 main pieces only, is the well-known Rites Inertia governor, located in a dustproof pocket on the outside of the flywheel, where it is always working in oil and is accessible. Admission of steam to the cylinders is regulated to govern engine speed from full load to no load on maximum 2½ per cent variation.

All bearings are continuously lubricated by a positive splash system contained in the crank case. The crank case is filled with water to such a height that the cranks just dip into it; a small quantity of heavy lubricating oil is then added, so that at every dip of the cranks the mixture is splashed to every part of the interior, where it collects in small pockets and flows in a continuous stream over all bearings. Externally there are only 2 small grease cups which require attention.

STURTEVANT ENGINES

B. F. Sturtevant Co., Hyde Park, Mass.

STURTEVANT engines are made in horizontal center crank and vertical, compound and simple types. All types are prvided with separate cast-iron sub-bases and frames with openinigs to give easy access to reciprocating parts, and are fitted with dust and oil proof covers, so as entirely to encase these parts.

Cylinders and valve chests of the horizontal and vertical engines are cast together, and are insulated with magnesia and covered with a steel lagging.

In the simple engines, the cylinder has large relief valves. The cored piston is fastened to the piston rod on a forced taper fit and secured with a nut and pin, the other end of the rod being held in the crosshead by a screw and jam nut; adjustable shoes provide for taking up the wear in the crosshead. The crosshead end of the connecting rod is solid with

brass boxes while the crankpin end is of malleable iron of the marine type, lined with white metal.

The steel shaft is forged in a single piece with counterweight bolted to the webs, and a centrifugal oiling ring set into the web and counterweight.

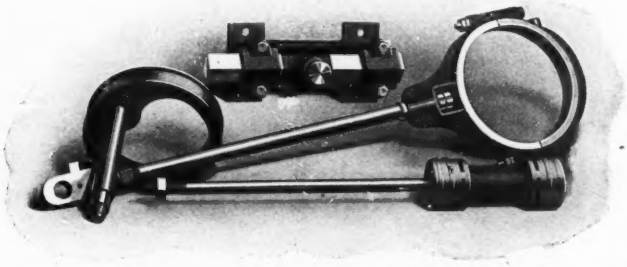


FIG. 2. STURTEVANT ECCENTRIC, STRAP, VALVE GEAR AND VALVE

A Rites governor, located in the flywheel, changes the throw of the eccentric, driving the valve through the eccentric rod, valve slide and valve rod. The valve rod has nuts and a yoke for valve adjustment

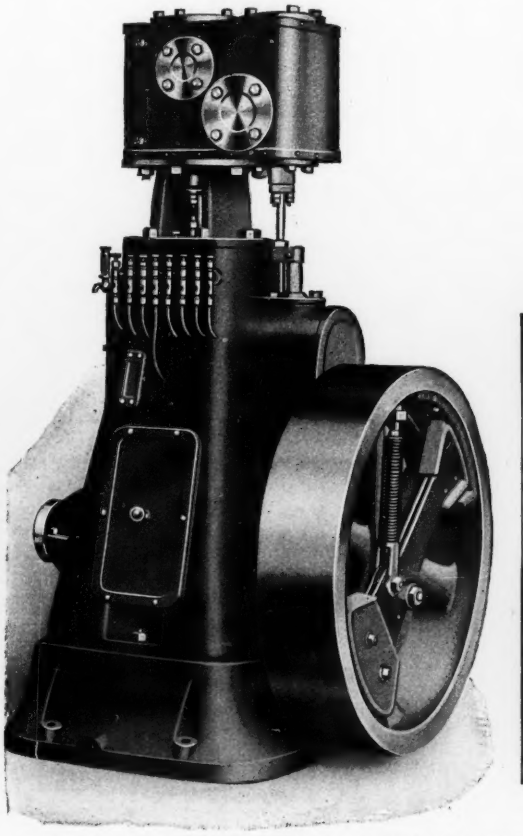


FIG. 3. STURTEVANT VERTICAL AUTOMATIC ENGINE

at the eccentric strap and a bronze box with strap to fit the slide pin at the slide end. The balanced piston valves work in removable bushings, the valve being screwed on the end of the rod.

In the horizontal type, lubrication is supplied by an elevated reservoir or tank, oil being conveyed to the bearing through piping from the tank.

In the vertical type, the oil reservoir is cast in the frame of the engine and is supplied with oil by a pump located in the base which contains a quantity of oil, and receives the drip from the bearings. A strainer located in the base cleans the oil before it is

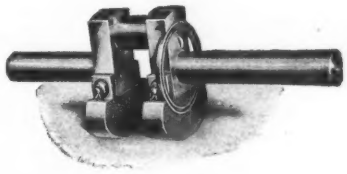


FIG. 4. CRANK SHAFT WITH COUNTERWEIGHTS AND CENTRIFUGAL OILER

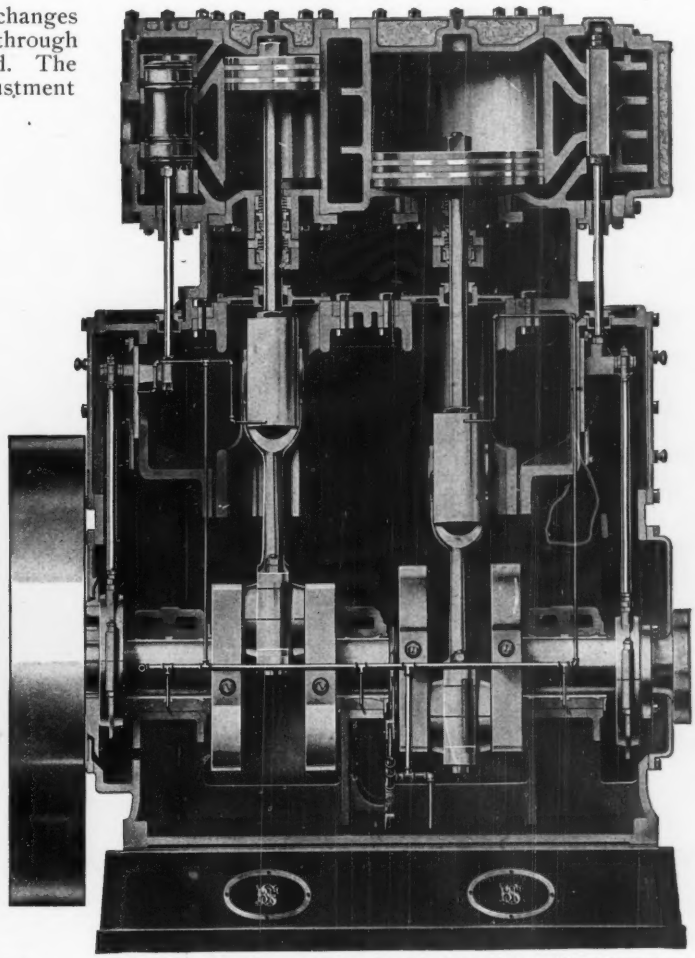


FIG. 5. SECTION OF THE STURTEVANT COMPOUND ENGINE

pumped into the reservoir, from which the oil flows into the carrying pipe through sight feed oilers. The oil is carried to the crankpin through a ring oiler in the web and pin.

In the vertical compound type the cylinders are fitted with bronze relief valves. The high-pressure valve is of the piston type and the low-pressure is a

flat slide valve with balancer plate, and is adjustable to regulate the receiver pressure and the power division between the 2 cylinders. At the crosshead end, the connecting rods are of the forked-end marine type, carrying a nickel steel pin flattened on the sides. A fit, the flat face being fitted with a special soft metallic packing which makes a perfectly steam tight seal between the cage and the cylinder. Steam pressure is sufficient to hold this cage up to the seat, and set screws passing through the steam chest cover hold the

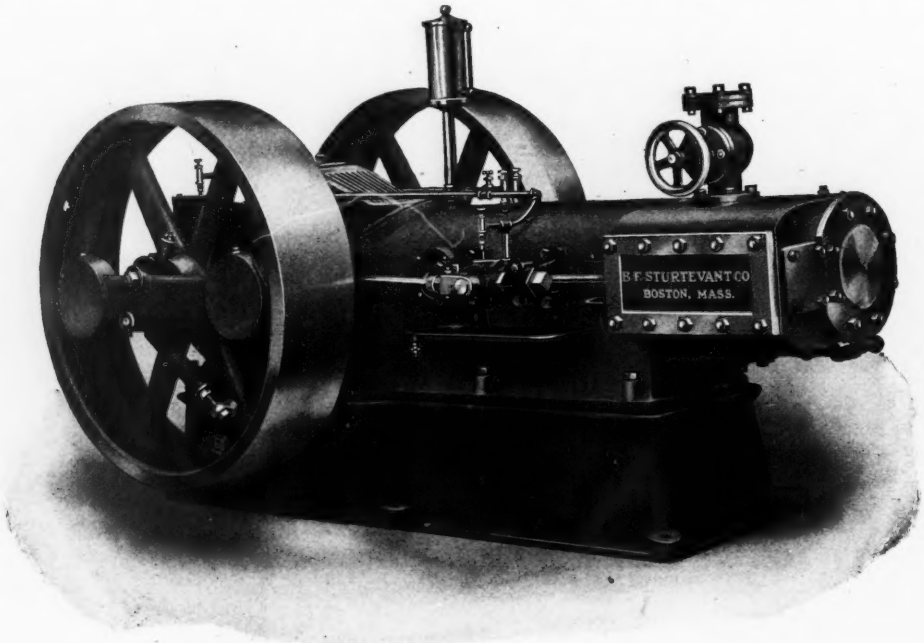


FIG. 1. STURTEVANT HORIZONTAL CENTER CRANK ENGINE

Rites governor is also used on the compound engines. The oil is forced at 12 lb. pressure through a system of oiling pipes to the bearings by an eccentrically driven pump located in the base, from a reservoir cast in the sub-base.

BAKER BALANCED PISTON VALVE

Baker Valve Co., Minneapolis, Minn.

THIS is a piston valve with 2 heads whose wearing surface consists of expansion rings so designed that under all conditions they will keep steam from working on their inner surface, and hence will not steam pack.

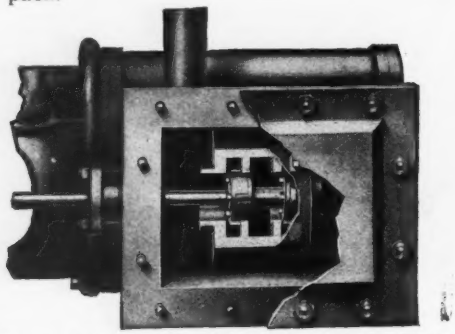


FIG. 1. BAKER VALVE ON SLIDE VALVE ENGINE

For slide valve engines it is fitted in a cage or valve chamber, semicircular on the back and flat on the face, which is placed in the steam chest and bears against the old valve seat. It is cored for ports exactly matching those in the cylinder which it is to cage in position at all times. Steam pressure filling the chest and surrounding the cage enters at either end and passes through the ports to the cylinder as the piston valve is moved alternately from end to end of the cage, slightly overtraveling at each end.

The Baker valve, when applied to an engine, becomes a part of the engine; it takes only a short time to apply it to any slide valve engine and it is a simple task to take the measurements needed to build it.

For piston valve engines the fitting is still simpler, as all that is needed is to take out the old piston valve and put in the Baker valve. When the valve chamber is worn by the old valve, a reamer is furnished with the new valve.

Some results obtained where Baker valves have been applied are in the Steamer Belle, belonging to the Independent Ferry Line, Duluth, Minn., which with a plain D valve, required 12 dump boxes of coal a day, and with a Baker valve gave the same service with only 8 dump boxes a day. In the Plaza Hotel, Minneapolis, 2 high-speed engines of the same make and size, run on alternate days; one has a 5-in. solid plug valve, the other a Baker valve. With the same load conditions on alternate days, the first engine required 1500 lb. of coal a day, while the second required 1200 lb., a saving of 20 per cent with the Baker Valve.

MERITAS MILLS, of Columbus, Ga., are progressing with the construction of a new addition, which will be 180 ft. long by 120 ft. wide, of slow-burning mill construction, costing about $40,000. The machinery to be added will include 16,000 spindles and 200 looms, costing about $150,000.

TWO VALVE ENGINES

Riding Valves to Increase Cutoff Range. Piston Valves to Reduce Friction. Separate Steam and Exhaust Valves to Lessen Condensation and Clearance

SOME of the difficulties encountered with the common D valve have been overcome by what is known as the riding cutoff valve. In the simplest form this consists of a modified D valve having steam ports through the valve, rather than allowing steam to pass to the cylinder around the ends; upon the main valve slides a smaller valve, operated by another eccentric, and controlled by the governor so as to cut the steam off at varying points of the stroke depending upon the load. The eccentric for this rider valve travels ahead of that for the main valve, so that at the time of cutoff the rider is traveling in a direction opposite to that of the main valve so that cutoff is rapid and wire drawing is minimized.

Principal among the advantages claimed for this type of valve is the ease with which cutoff can be regulated by the governor. Being light in weight little power is needed to operate the rider valve, and the drag upon the governor in changing the position of cutoff is slight so that regulation secured by engines equipped with riding cutoff valves should be very close.

With this type of valve it is common to employ little or no steam lap on the main valve by which means it is possible to secure a wide range of cutoff, from 0 to ¾ stroke.

Piston Valves

MECHANICAL difficulties in balancing flat slide valves have led to the use of piston or cylindrical valves employing a cutoff valve. The principle upon which the cylindrical valve operates is precisely the same as that of the flat valve. Figure 2 represents a general type of riding cutoff piston valve. The main valve consists of 2 cylinders closed at their outer ends and connected together by 2 bars, the round cutoff valve working within the main valve. The main valve

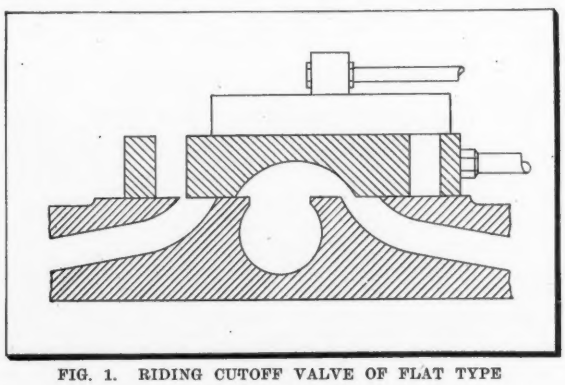


FIG. 1. RIDING CUTOFF VALVE OF FLAT TYPE

seat consists of a bushing placed in the casting. Steam is admitted to the cylinder from the interior of the main valve, and exhausted past the ends.

Setting Riding Cutoff Valves

TO set the main valve of an engine with a riding cutoff valve proceed as with a common D valve by equalizing the lead at both ends so that the valve has about 1/64 in. lead at each end. The main eccentric is then made fast to the shaft and the setting of the cutoff proceeded with.

Different portions of the stroke are laid out along the crosshead slide from each end of the stroke; with the crosshead in the position at which it is desired that cutoff should take place, the cutoff valve is adjusted so that it just closes the port in the main valve. The engine is then moved to the corresponding position in the return stroke when the cutoff valve should just

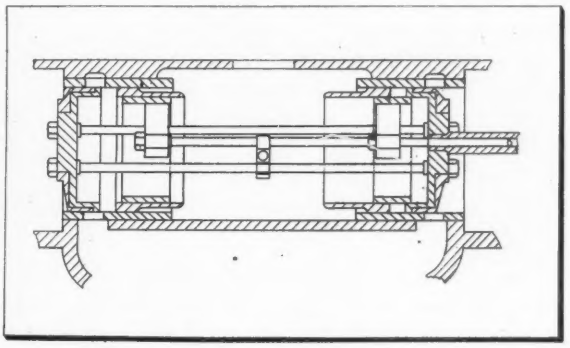


FIG. 2. RIDING CUTOFF PISTON VALVE

close the port in the main valve; if it does not, the length of the valve rod should be changed and the cutoff eccentric shifted until equal cutoff is obtained at both ends.

Separate Steam and Exhaust Valves

ANOTHER form of 2-valve engine has one valve for admitting steam and a second valve for exhausting, placed at opposite sides of the cylinder so that exhaust steam is not required to go through the same ports as does live steam; consequently there is little change in the temperature of the steam ports and initial condensation is reduced.

It is also possible to secure automatic cutoff by this arrangement without in any way affecting exhaust events of the cycle.

While, strictly speaking, this type of valve is not now being used there are several modifications which go by the name of 4-valve engines, eminent among them being the Russell engine.

The object of using 4 instead of 2 valves is to reduce the length of ports and clearance space, and as the 2 steam valves also the 2 exhaust valves are joined, it gives the effect of 2 valves, one for steam and one for exhaust with the added advantage of short ports.

Use of 2 valves also permits thorough draining of the cylinder at each stroke, since the exhaust ports can be placed in the bottom of the cylinder.

THE BROWN ENGINE

Brown Engine Co., Fitchburg, Mass.

THE Brown engine is built with either girder or heavy duty Tangye frame. The girder frame is cast separate from the pedestal for the main bearing, which is rigid in construction and has a liberal pad to which the frame is bolted. The pedestal is bored to receive the lower shell which is turned concentric with the shaft and can be removed by raising the shaft enough to relieve the weight.

The girder frame is heavily ribbed and has bored guides, while a large pad is provided under the forward end of the guide barrel to receive a supporting pedestal.

The heavy duty tangye frame has a separate bored guide barrel, accurately faced and bolted to the forward section which has a continuous bearing on the foundation and contains an oil pan under the crank. The general construction of the tangye main bearing is similar to that of the girder frame, except that the lower shell is made in 2 pieces, the inner one, concentric with the shaft, and the lower one, accessible to the hand through a cored hole in the front of the pedestal.

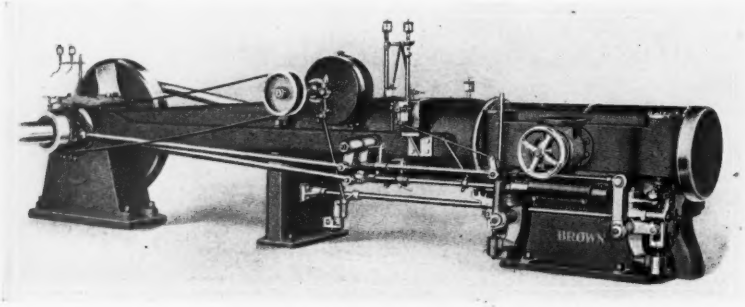


FIG. 1. VALVE GEAR SIDE OF BROWN GIRDER FRAME ENGINE

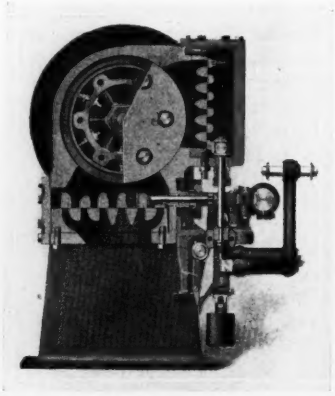


FIG. 2. SECTION THROUGH CYLINDER AND VALVES OF BROWN ENGINE

The cylinder has 4 flat multiported valves, 2 each for steam and exhaust, the former being located on the side of the cylinder, and the latter at the bottom, with ports liberal and direct. Valves and their seats are held in bored recesses provided for them in the body of the cylinder and are located close to the bore, reducing the clearance to a minimum.

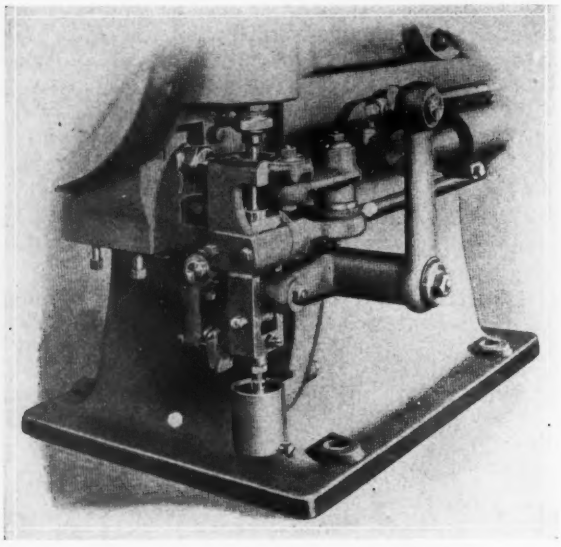


FIG. 3. VALVE MECHANISM OF BROWN ENGINE

Steam valves are operated by offset bell-cranks connected by a steam rod, the forward one of which is driven by the steam eccentric through the usual carrier arm. The valve is opened upward and the latch releases the block at any point determined by the governor, when the valve closes by its own weight assisted by the pressure on top of the valve equal to the unbalanced area of the valve stem. Trip levers are carried by a trip shaft which is under control of the governor.

Exhaust valves are operated by an eccentric which drives a sliding bar to which the exhaust levers are attached by means of a link.

The governor is of the inertia type, and is connected direct to the trip shaft running below the frame by a suitable bell crank.

The piston, well ribbed and strong, with a single adjustable bull ring and 2 packing rings, is pressed on the rod and fastened with a nut, and the nut covered with the follower plate.

The crosshead is of cast iron with flat parallel surfaces to which are attached the babbitt-lined gibs of box type with independent wedge which is adjusted by a bolt running the entire length of the gib.

The connecting rod is of the solid end type with babbitt lined phosphor bronze boxes with vertical wedges adjusted by bolts from the top and bottom of the rod.

Full details in regard to valve setting were in Practical Engineer for January 1, 1912, page 20.

THE BUCKEYE ENGINE

Buckeye Engine Co., Salem, Ohio

BUCKEYE engines are characterized by a balanced cylindrical valve with which a riding cutoff valve is used. This valve has a uniform travel and adequate seating area so that there is no tendency to wear shoulders.

The movement of the cutoff valve, whether cutting off early or late in the stroke always does so near the middle of its travel where its motion is fastest, and always continues to move after closure to the extent of over one-third of its travel.

As will be seen by referring to cut, the close proximity of the valve to the bore of the cylinder and of the cutoff valve to the main valve face, together with the absence of separate exhaust ports, constitute conditions under which the clearance may be reduced to a minimum.

The governor being secured directly on the engine shaft, and driving its valve as positively as the main valve, through an eccentric rod, rock shaft, and valve stem, the danger of the engine becoming detached from it and destroying itself and the lives of those in its vicinity, is entirely obviated.

Simplicity also follows from the nature and location of the governor. It is, both in appearance and effect, a part of the engine itself.

It is characteristic of the Buckeye engine that it possesses great stability in the adjustments by which the cutoff is made to take place at the same distance from the beginning of both strokes. The variations of the point of cutoff required for regulation being affected by variations in the advance of the eccentric which moves the cutoff valve, must necessarily be equal for both strokes, hence when it is equalized for the average position, it will be practically equal at all other positions within any required working range. Also, the cutoff being affected by the passage of the cutoff valve over the port when at the fastest part of the travel (of from 2 to 5 in. according to size), is not sensibly affected by a degree of misadjustment.

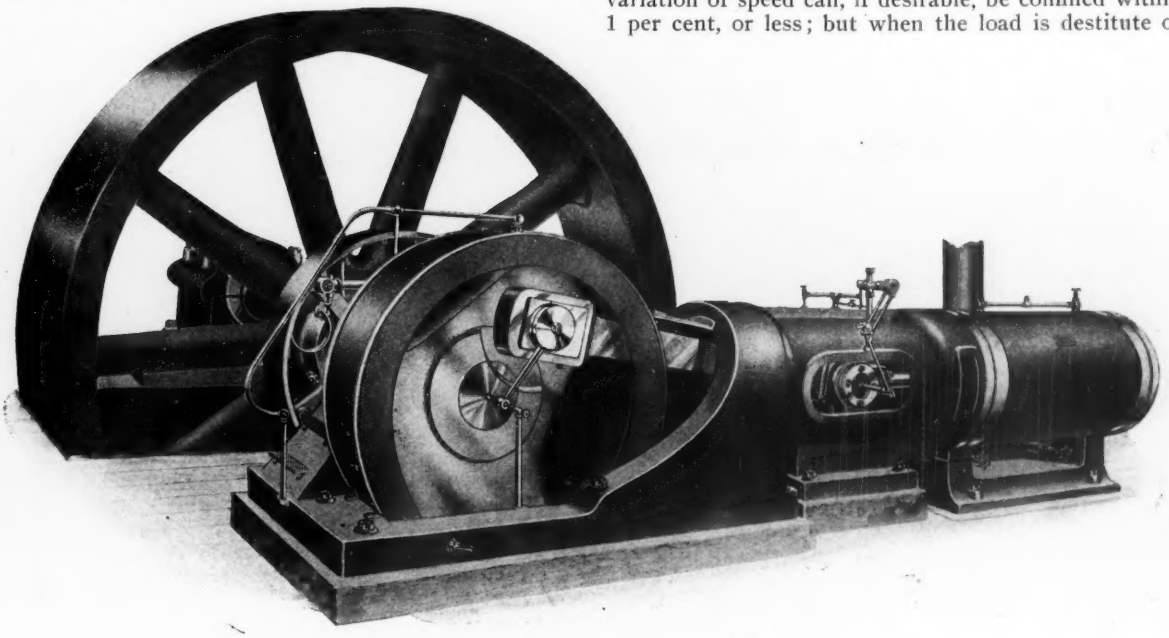


FIG. 1. HEAVY DUTY CLASS A BUCKEYE SINGLE ENGINE

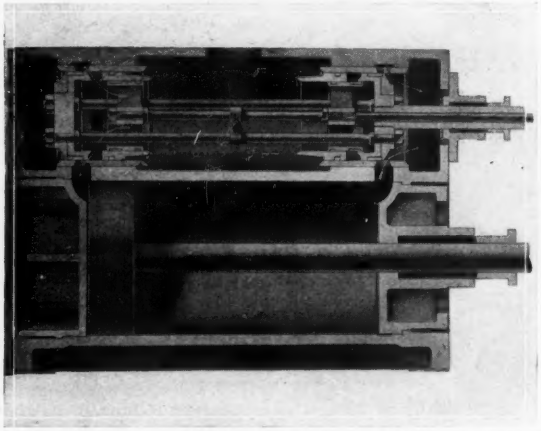


FIG. 2. SECTIONAL VIEW OF BUCKEYE CYLINDER AND VALVES

The construction of the governor permits such an adjustment of the centrifugal and centripetal forces to each other as will give in each case as close regulation as the nature of the conditions which effect the action of the governor will permit. If the machinery driven, contains in itself considerable momentum to assist that of the flywheel, and is not subject to sudden and extreme changes of resistance, the conditions are favorable to close regulation, and in such cases the variation of speed can, if desirable, be confined within 1 per cent, or less; but when the load is destitute of momentum or vis viva, and is subject to great and sudden changes, it may be necessary to adjust for a greater variation, according to the nature of the load.

The percentage of variation is adjustable at will, by varying the amount of initial tension given to the governor springs—the more initial tension the closer the regulation, within the limits beyond which the necessary stability of equilibrium would be lost.

Buckeye engines are built in types and speed to meet all requirements of reciprocating engines from 30 to 4000 hp.

FITCHBURG ENGINES

The Fitchburg Steam Engine Co., Fitchburg, Mass.

DISTINCTLY characteristic of the Fitchburg engine are the valves and valve motion which, although it has the Corliss wrist plate action, is as simple as the common slide valve motion and as readily accessible. It is a cam valve motion, which is positive, noiseless in operation, of great durability, and perfectly reliable. The Corliss wrist action is used to actuate the admission valves without releasing or tripping them. The valves are driven by a shaft governor which controls by shifting the eccentric across the shaft, changing the angle of advance of the eccentric and therefore the time of cutoff.

The peculiarity of the valve motion consists of the specially shaped cams, into which the steam valve rods are fastened to drive the valves, and the mode of using the Corliss wrist action by which these cams are actuated. This Corliss wrist action and the double ports in the steam valves give clean admission and sharp cutoff.

Steam is always around and at both ends of the valves in the steam chest, not only giving an even heat and expansion the whole length of the valve seat, but balancing the valves in their movement with the

While in every respect the valve is the same in service as a solid valve without packing rings, it has provision for enlargement in diameter by means of a taper cone inside of an expansible shell, giving truly

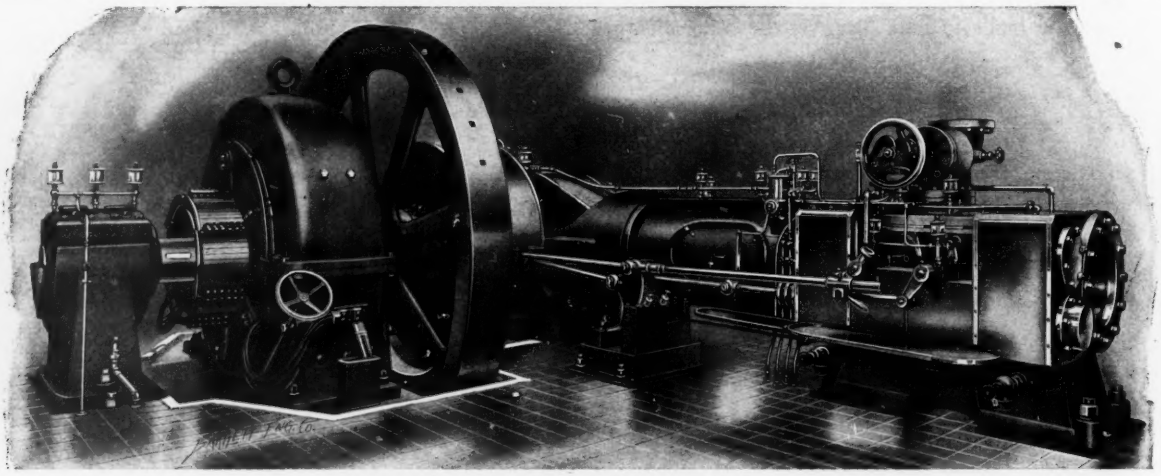


FIG. 1. DIRECT CONNECTED FITCHBURG ENGINE WITH TANGYE BED

exception of the area of the valve stems. This small unbalanced area is just enough to keep the cam at all times against its driving roll, acting as an automatic spring and giving a quiet motion at all speeds.

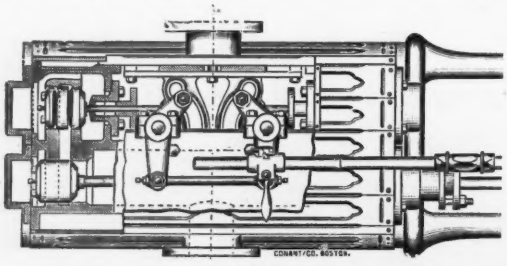


FIG. 2. WRIST PLATE VALVE MOTION OF FITCHBURG ENGINE

The unbalanced area of rod spoken of above serves also as a safety device, for if the driving latch should become detached by accident, or if the valve rod or eccentric rod should become detached or break, the

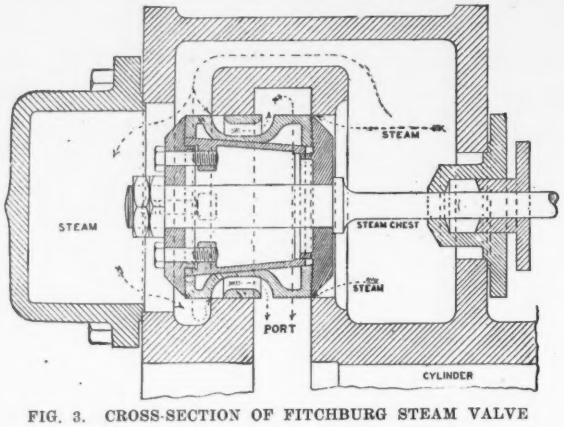


FIG. 3. CROSS-SECTION OF FITCHBURG STEAM VALVE

valves are instantly closed automatically by the unbalanced pressure on the rods, and all steam is shut away from the piston. The steam valves are double ported.

symmetrical enlargement from 1/10,000 in. to 1/16 in. in diameter. All 4 valves are of this type.

Each of the 4 valves can be set entirely independent of the others and the inlet and exhaust valves are driven by separate eccentrics.

The passage through which the exhaust steam travels is cast away from the cylinder and a space is left between the cylinder wall and this passage, avoiding loss of heat from the cylinder to the exhaust due to the difference between the temperature of the steam in the cylinder and of that in the exhaust passages.

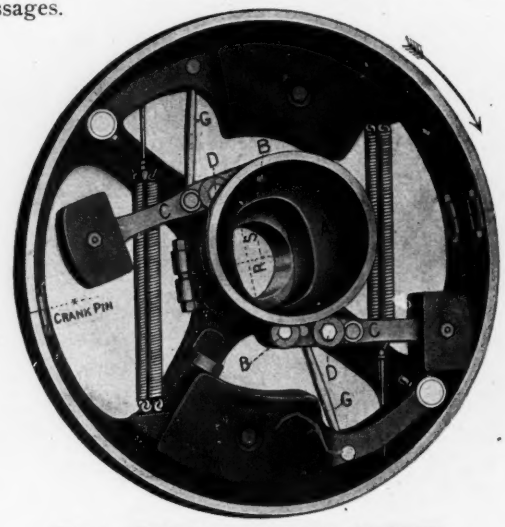


FIG. 4. FITCHBURG FLYWHEEL GOVERNOR

Governing is done by changing the angle of advance of the eccentric. As long as the engine is below speed the eccentric A is kept in its longest throw by the tension of the long adjusting springs, causing the steam to be cut off at about 7/10 of the stroke, but as soon as the proper speed is reached the centrifugal action causes the weight arms H to overcome the tension of the springs and to move outward, at the same time lengthening the springs.

Also the outward motion of the weight arms through the connecting links G, turns the counterbalance arms C upon their fulcra D, and the eccentric, attached at ears B, is consequently carried directly across the shaft from S towards R, and as the arcs made by the centres BB are in opposite curves they compensate each other, and the center S of the eccentric follows a straight line in its movement, presenting a constant lead opening.

This decreases the eccentricity and increases the advance of the eccentric, giving an earlier cutoff to the valves until when the eccentric is swung squarely back of the crank the valves open only the lead, there being all points between this and extreme cutoff for variation.

Four different types of beds or frames are employed with Fitchburg engines. The rolling mill or tangye frame, the girder frame, the vertical frame and the high speed frame. The beds or frames are of massive design, and the general form and the distribution of metal is such as to insure the greatest strength and rigidity in the proper places to resist the varying strains caused by heavy and sudden overloads.

RUSSELL 4-VALVE ENGINE

Griscom-Russell Co., New York, N. Y.

THIS is designed especially for heavy mill and power plant purposes.

Its distinctive feature is its flat main valve with riding cutoff valve actuated by a shaft governor, giving quick port opening and closing, and freedom from uneven wear and consequent leakage. Further, no exhaust steam passes through the steam-chest or near the steam admission line close up to boiler pressure with sharp cutoff.

Steam economy, however, can hardly be considered more important than strength, durability and reliability in service. In these respects, careful thought has been given by the designers of the Russell Engine to the frame, cylinder and moving parts. The frame is a casting, of smooth and symmetrical shape, with stiffening ribs of ample dimensions within the hollow interior. The guides are bored, and the crosshead is turned to correspond—an excellent feature with the side crank type of engine. The crosshead body is of cast steel, and the shoes are babbit faced, and adjustable by taper wedges.

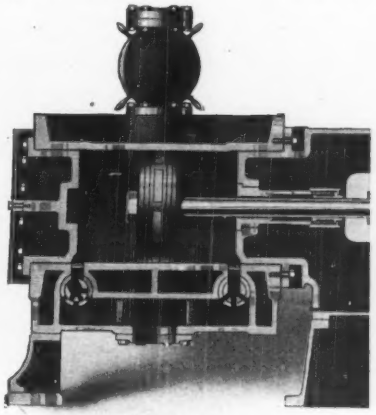


FIG. 1. SECTIONAL VIEW OF RUSSELL 4-VALVE ENGINE

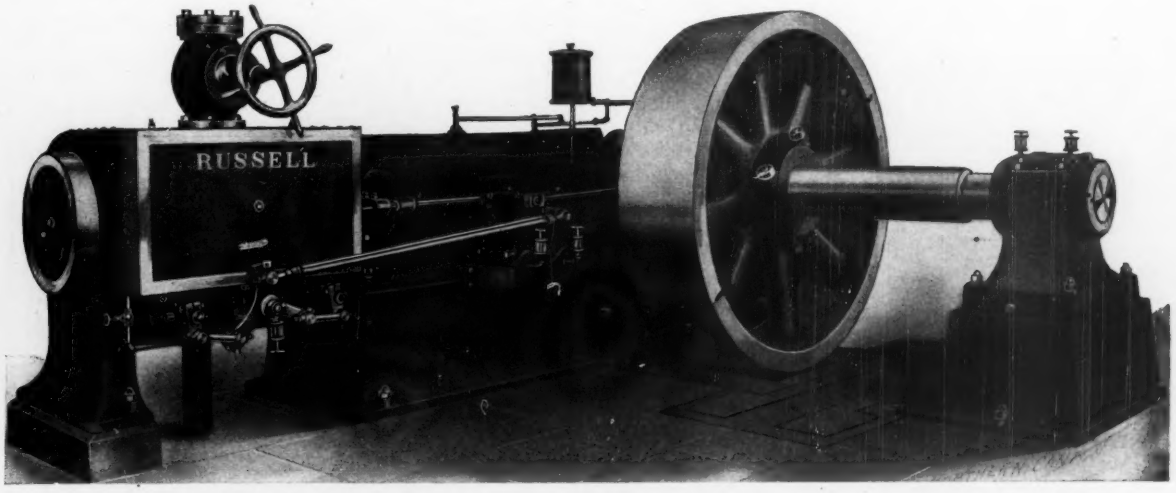


FIG. 3. RUSSELL TANDEM-COMPOUND, 4-VALVE ENGINE

the steam inlet-valve, to cause cooling and condensation of the live steam on the way to the cylinder. Instead, the exhaust valves are of Corliss type placed directly below the cylinder, and actuated by a simple, light and effective wrist motion driven from a fixed eccentric.

The cylinder is thus effectively drained of condensation without depending on the lifting of the inlet valves from their seats, though these are in fact free to relieve in this way if it were required.

The economy realized by Russell 4-valve engines is good, because of great port opening which keeps

At the rear of the guides is a watershed with simple but effective auxiliary stuffing box to prevent the water of condensation from following the piston rod and mingling with the oil in the splash oiler under the crank.

A door at the side permits access to the crosshead and adjacent parts, and liberal hand holes on either side, permit easy access to the main stuffing box.

The main bearing has a large oil reservoir beneath, connected with a gage glass in front and a large oiling chain to flood the shaft journal. The bearing is of 3-piece type, consisting of a bottom shell, and 2 side

shells which lap over on top, where the cap holds them in position. Adjustment is secured by a full width wedge back of the shaft, lifted as required by screws on top of the cap. By removing the side plates and wedges, the side shells can be removed, after which the shaft can be slightly raised and the bottom shell slipped out without disconnecting the engine.

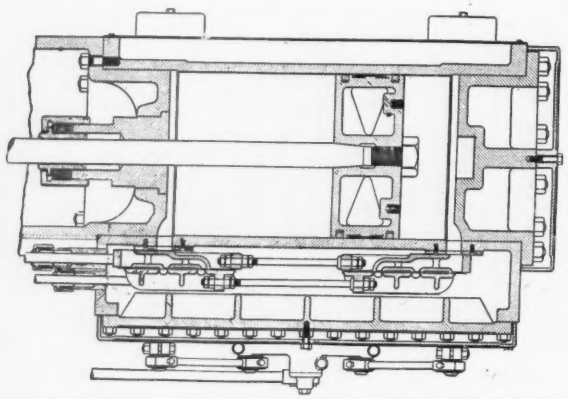


FIG. 2. RUSSELL 4-VALVE, SHOWING STEAM VALVES AND VALVE GEAR

The cylinder and valve arrangement includes several interesting features. The generous size main steam ports are cast in the cylinder as usual, and over the port faces are secured false seats of tough, close-grained cast-iron, in which the port openings are exactly milled to size. These false seats can be removed, refaced or replaced, should it ever become desirable. The exhaust valve chambers also have accurate port openings, provided by means of bushings, reamed and ground to exact size, and pressed firmly into place in the cylinder casting.

The valves are actuated by 2 fixed eccentrics. One of these is for the main valves and operates them to give proper lead; the other is for the exhaust valves, and by means of the wristplate and links gives the valves the proper quick opening and closing movements, and permits them to rest motionless when closed and under pressure. The centrifugal shaft governor which operates the cutoff valves is of the Russell centrifugal type, with 2 opposite and equal arms, weights and springs, so that it is in exact balance in all positions. The position of spring attachment to the weight arms can be changed, as well as the tension of the springs, which permits a wide range of speed changes, and adjustment for close regulation at any desired speed. The cut-off eccentric turns around the shaft under the action of the governor, to vary the point of cutoff according to the load. The entire governor can be assembled to run in either direction, without altering any of the parts except as to position.

McINTOSH & SEYMOUR TYPE F ENGINE

McIntosh & Seymour Co., Auburn, N. Y.

THESE engines are of the 4-valve type with positive motion valve gear and powerful shaft governor. A distinctive feature of the engine is the gridiron valves, located in the cylinder heads, which gives the smallest possible clearance space, and with short and direct nozzle-shaped steam ports delivers the steam with a minimum drop for a given opening directly into the center of the steam space in the cylinder, reducing agitation of steam against the cooling cylinder walls.

Gridiron valves follow up their wear, maintaining high economy over long periods, both valves and seats being arranged with grooves, so that they always wipe over to prevent wearing of shoulders. These wipe-over grooves are made extra large and arranged so that the steam is admitted at both sides of the port, giving for most of the useful loads a double ported effect. The total length of port thus available is about 6 times the cylinder diameter, giving large steam opening with moderate valve travel. Also placing the valves in the heads permits of a plain barrel cylinder with 2 flanges.

The box type piston has a sectional packing ring and 4 rings of antifriction metal. The frame, which encloses most of the working parts, is yet open enough to give easy access. At the cylinder end the upper part of the hood is omitted, bolting to the cylinder being only on the lower ⅔ of the bolt circle. This arrangement leaves the steam chest free to expand without affecting the alinement of the cylinder.

Guides are of the bored type, with the web member forming the lower part continued under the crank, giving stiffness to the frame and forming an oil receptacle.

The main bearing has a cylindrical shell which can be easily removed by taking off the weight of the shaft. It is also provided with a thick cheek piece, when the cap is bolted down it cannot rock, this piece being held against the shaft by 2 wedges.

The skeleton type steel crosshead has babbitted cast-iron slippers; the crosshead fits between 2 shoulders on the slipper, which is held to the crosshead with 4 bolts so that it cannot get out of place. Adjustment is by thin metal liners between the slipper and crosshead.

The solid-end connecting rod has wedge and bolt adjustment, but in the boxes are 4 opposing screws, which can be set up after the box has been keyed, to take out any slight spring.

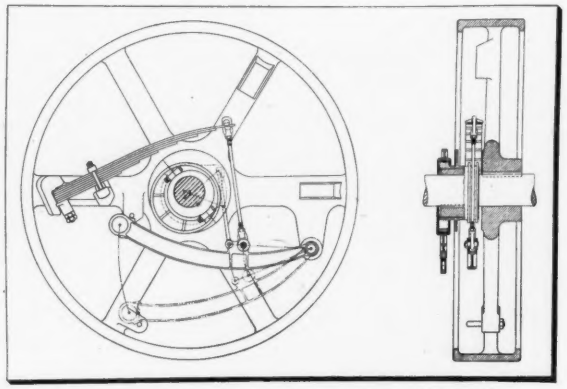


FIG. 4. MCINTOSH AND SEYMOUR GOVERNOR

For both steam and exhaust valves the gear is a positive motion throughout, with pins taper fitted and supported at both ends. All joints subject to wear are provided with grease lubrication, and for adjustment, which is reduced by case hardening the pins.

At the cylinder are lay shafts oscillated in babbit lined ends. Fitting each ball is a spherical box bolted directly to the eccentric strap.

Figure 4 shows the governor of the shaft type with cast steel weight, opposed by a plate spring. This weight turns the governor eccentric on an eccentric

bearing which is keyed to the shaft, giving the effect of a very short pendulum, insuring constant admission at working loads, and at zero load swinging the governor eccentric center rapidly toward the center of the shaft, and reducing cutoff to zero. In this construction the static force of the weight is balanced by the eccentric and strap.

Working parts are practically enclosed by the frame and oil shields, all oil from the running parts being collected in a tank below the floor, where water is separated from the oil, which passes through a strainer and then through a filtering compartment into the settling chamber, whence it is lifted into the receiving tank on top of the frame by a small pump actuated from the valve gear; thence, the oil is distributed by pipes to the various parts of the engne. From each end of the main bearing, oil is led by a small pipe to one of the lay shaft bearings. The exhaust eccentric is provided with a double contrifugal oiler, one part of which lubricates the exhaust eccentric strap, this having retaining walls on each side so that oil which works out feeds on down to the ball and socket joint. The other centrifugal oiler delivers oil through a pipe to the exhaust of the loose eccentric on the governor, whence it feeds through to the governor eccentric strap, provided with retaining lips, and down to the ball and socket connection driving the steam lay shaft.

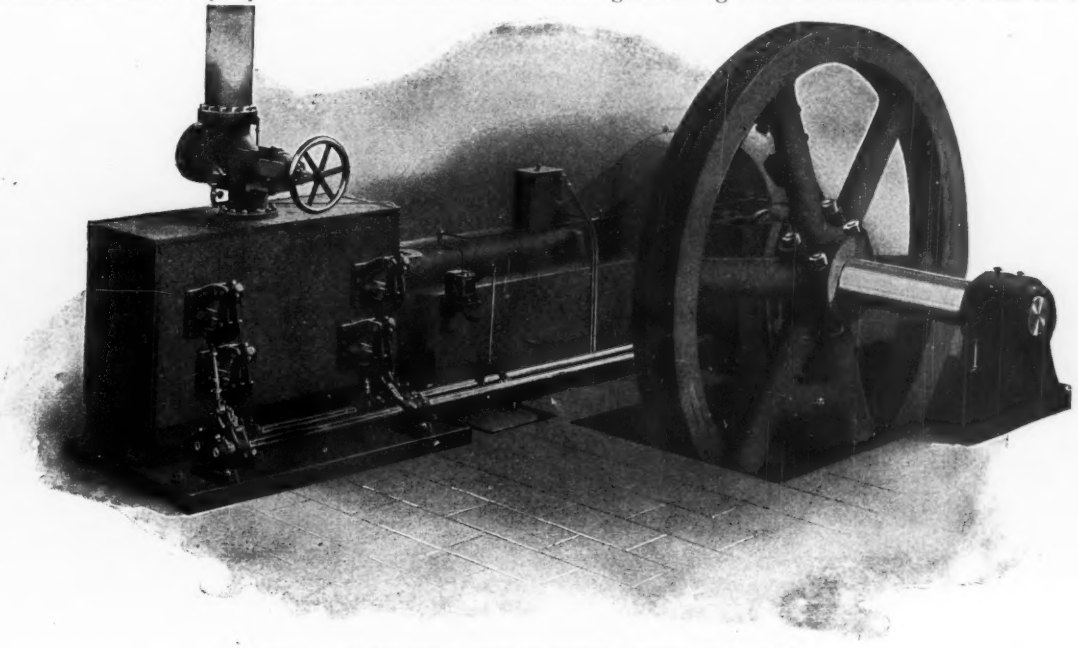


FIG. 1. VALVE GEAR SIDE OF SINGLE CYLINDER ENGINE

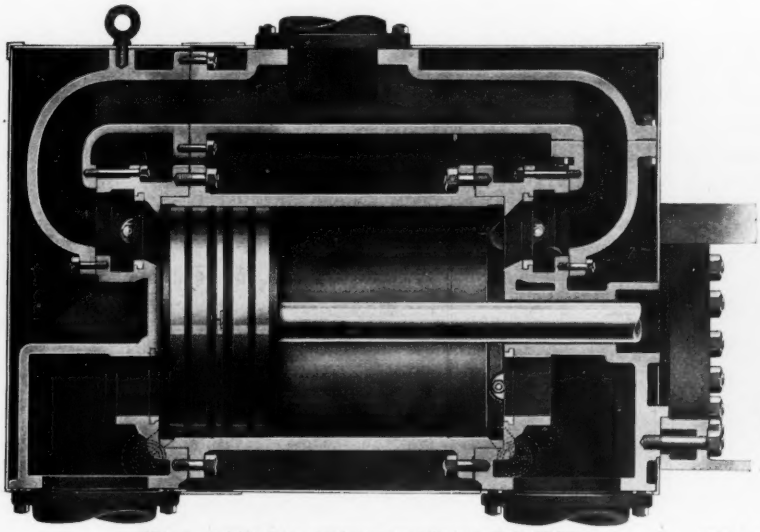


FIG. 2. VERTICAL SECTION THROUGH CYLINDER

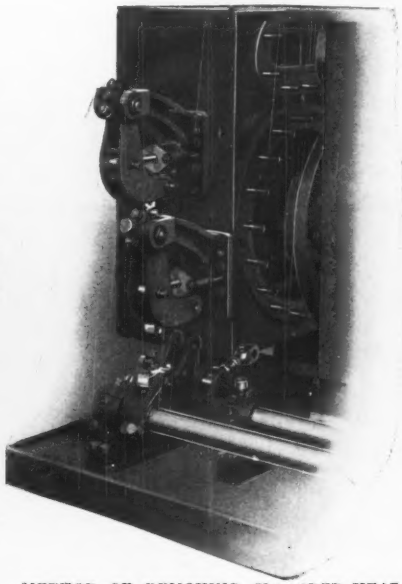


FIG. 3. METHOD OF REMOVING CYLINDER HEAD

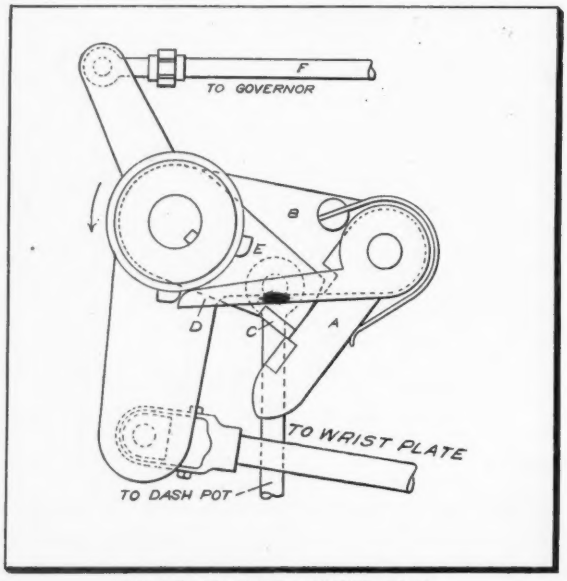
To gain access to the steam valves, the steam valve bonnet has a ground joint on the face of the cylinder, and by removing one taper valve gear pin and the nuts holding the bonnet in place, bonnet valve and all can be taken out.

CORLISS ENGINES

Early Development, Distinctive Features, Present Day Applications of Original Design

TO GEORGE H. CORLISS credit is due for designing what was at that time the most radical departure from standard practice in steam engine manufacture. Previous to that time, 62 years ago the simple D slide valve was the standard means for controlling the admission and exhaust of steam in the cylinders of stationary engines. With this valve gear the cutoff was fixed usually at about ¾ stroke, and the speed of the engine was regulated by a flyball throttling governor which operated by wire drawing the steam, making the entire operation wasteful and inefficient.

To relize any great degree of economy, some radical departure in the details of the old time engine was necessary and Mr. Corliss set about the design of an



THE CRABCLAW RELEASING GEAR

engine in which there was scarcely a resemblance to other engines then existing and the distinctive features of his engine are embodied in Corliss engines of the present day.

The essential features of a Corliss engine are: first, its 4 semi-rotary valves, 2 steam and 2 exhaust, the latter placed at the bottom of the cylinder to drain out condensation, and all the valves located in such a manner as to reduce clearance to a minimum.

Second, the employment of an eccentric on the main shaft operating the several valves through radial arms in such a manner as to obtain rapid opening and closing of the valves, to give full port opening.

Third, a means of releasing the steam valves from the driving mechanism at the proper point in the stroke and closing the valve quickly by means of vacuum dashpots.

Fourth, a governor driven from the main shaft, and so arranged as to be entirely independent of the valve gear, its only purpose being to determine the point at which release shall occur according to the load on the engine.

By means of right and left hand thread connections on the radial arms, any valve may be adjusted independently of the other, and the amount of lead, point of exhaust and amount of compression remain the same at whatever point of the stroke cutoff may occur, making it possible to obtain a nearly ideal indicator diagram from a Corliss engine and insuring that the steam will be worked to the best advantage. As the steam valves are opened quickly by means of the bell crank connections, wire drawing is avoided. Quick closing of the steam valves by the suction of the dashpots further reduces wire drawing and allows the expansive energy of the steam to be fully realized in the cylinder.

The characteristics of the releasing gear, which is the most important feature of Corliss engine construction are a hook or crab claw, shown at A in the illustration, on the bell crank lever B, which hook engages a block C on the valve stem crank arm, raising the valve until the inner member of the hook B comes in contact with the block E, causing the valve to be released, thus cutting off the steam. The block E is mounted on a sleeve, which is free to turn and connected to the governor arm F, the governor varying its position according to the load on the engine.

Valves of modern Corliss engines are generally double-ported, separate from the valve stem and are driven by a T-head connection, which allows the valve to be removed without disturbing the valve mechanism.

Exhaust valves are operated from the wristplate by a single crank lever, as it is simpler to time their opening and closing by the amount of lap, rather than by a bell crank lever as in the case of the steam valves.

ALLIS-CHALMERS ENGINE

Allis-Chalmers Co., Milwaukee, Wis.

ALLIS-CHALMERS Corliss engines of their new design combine the latest developments with the best features of their previous designs. They are built in all sizes and in all horizontal and vertical arrangements.

The frame and slide form a massive one-piece casting with broad bearing surface on the foundations throughout the entire length, insuring the maximum of strength and rigidity. The end of the slide has a recessed flange for the cylinder head and all ribs and braces are inside the casting, giving a smooth, easily cleaned, outer surface. The frame proper is of the "tangye" type with unusually heavy pawls for the main bearing. A beaded oil flange surrounds the casting at its base and a deep crank pit provides for the collection and draining of oil from the several bearings.

Completely enclosing the crank and connecting rod is a sheet steel oil guard fitted with wire netting doors of ample size to permit adjustment or removal of crank pin boxes and to afford air circulation at the same time preventing the throwing of oil. The eccentric oil guards are also designed to collect the drip from the main bearing and to prevent oil creeping along the shaft.

The main bearing is of the 4-part type with full length adjusting wedges on each side to maintain a constant shaft center, thus reducing the danger from hot bearings. A spherical seated bottom shell insures perfect alinement with the shaft. The cap is integral with the top shell and has a drive fit over the bearing jaws. The entire design is such that all shells can easily be removed by simply relieving the weight of the shaft.

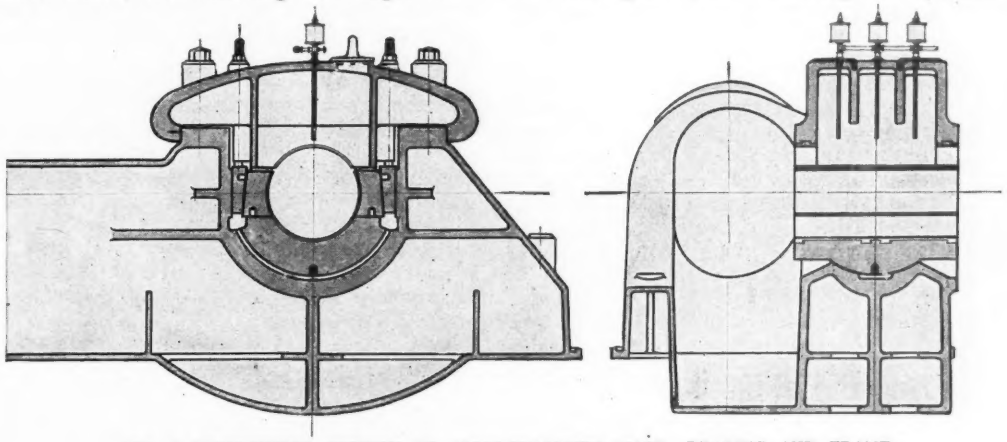


FIG. 3. LENGTHWISE SECTION OF ALLIS-CHALMERS MAIN BEARING AND FRAME

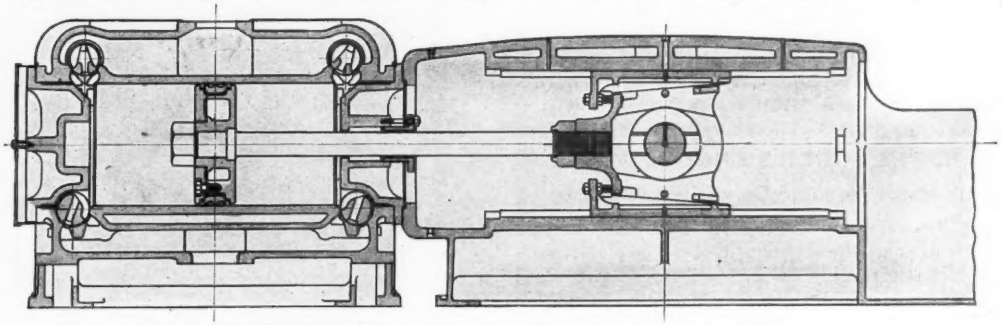


FIG. 2. SECTION OF ALLIS-CHALMERS CYLINDER AND FRAME

The cylinder is designed with the valves in the corners and so arranged as to reduce clearance to a minimum, thus obtaining the advantages of valves in the cylinder heads as regards low clearance and high economy without the disadvantage of disconnecting the valve gear when removing the cylinder heads.

Steam and exhaust valves are of the multi-ported Corliss type, which give rapid port opening with a minimum of travel, thus reducing the inertia of the valve gear parts and permitting higher rotative speeds. The steam valves are of the 3-bar construction, making a stiff symmetrical valve, which retains its form without distortion when used with high-pressure steam and superheat.

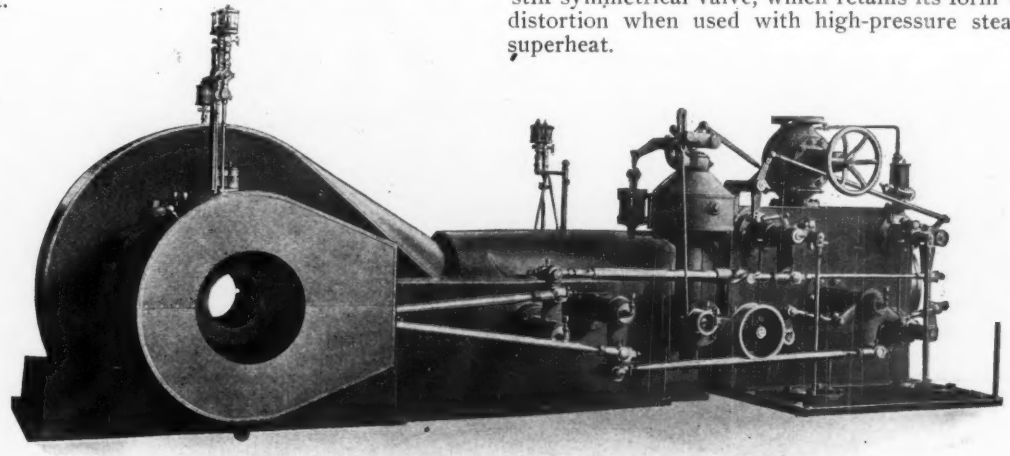


FIG. 1. VALVE GEAR SIDE OF ALLIS-CHALMERS ENGINE

The valve gear is of the long range type, permitting a range of cutoff up to 75 per cent of the stroke under governor control. Separate steam and exhaust

eccentrics allow independent adjustment of the steam and exhaust valves to obtain the best possible steam distribution. The steam valves are driven direct from one eccentric without a wristplate, thus reducing the number of heavy moving parts and making higher rotative speeds possible. The dashpots are of the improved spring-actuated, quick-acting type with cushioning chamber. The steam reach rod is fitted with a patented disconnecting device of a telescopic type with centering pin and special clamping sleeve to remove all strain from the pin.

The pistons are wide faced with red metal rings and 2 snap packing rings. The smaller pistons are of the one-piece box type while in the larger sizes they are built up of such design that the rings can be removed without taking the piston from the cylinder. The follower studs are fitted with shoulders to prevent broken studs from working out into the cylinder.

A new and important feature is the special high speed single tension spring governor. The advantage of a single spring in tension over 2 springs in either tension or compression is indisputable and there is no chance of this type of governor being out of balance on account of the springs not being matched. Although very simple in design, this governor permits a wide range in speed regulation by changing the number of working coils and the tension of the spring. All the rotating parts are enclosed in a stationary cast-iron case to prevent the throwing of oil and the bearings are flooded with oil from a special pump for this purpose so that wear and friction are minimized.

BATES CORLISS ENGINE

The Bates Machine Co., Joliet, Ill.

THE Bates heavy duty frame, which is cast in one piece in all sizes and has bored guides, is well proportioned to resist the strains of severe work. The main bearing is of the 4-piece type, strong and simple in design with wedge adjustment for the quarter boxes, the adjusting bolts projecting above the cap where they are locked in position with nuts. There is considerable clearance for the lower shell or bearing to move sidewise which permits it to adjust itself to any change in the position of the shaft. By raising the shaft slightly, the lower shell can be rotated around the shaft and removed.

The cylinder rests on a sole plate which extends under the valve gear, in which the dashpots are set flush with the deck.

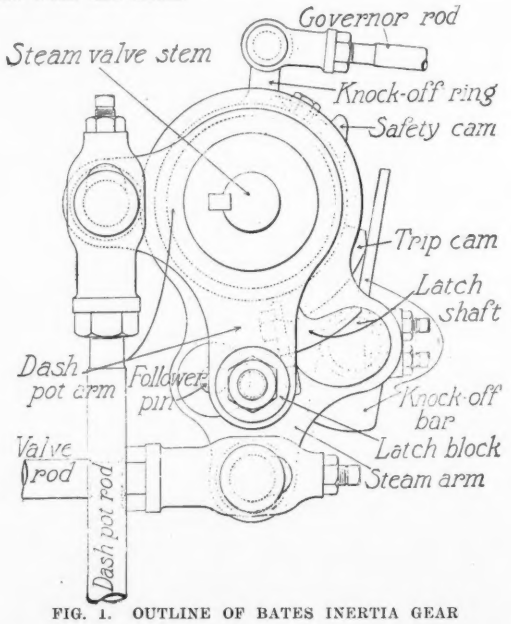


FIG. 1. OUTLINE OF BATES INERTIA GEAR

The valve gear is of the New Bates inertia type which has no hooks, springs or rollers and operates quickly at highest speeds. The general arrangement of the Bates inertia gear is clearly shown in the Figs. 1 and 2.

Referring to Fig. 1, the top lever is in the form of a bell crank, one arm carrying the dashpot and the other the latch block. This bell crank is keyed to the valve stem and also is a running fit in a recess bored in the steam bonnet which gives a large wearing surface.

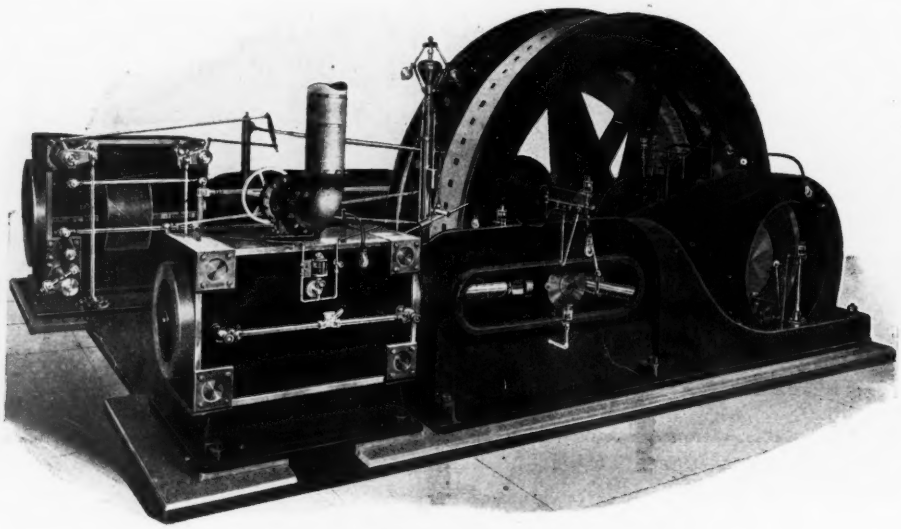


FIG. 3. BATES HEAVY DUTY CROSS COMPOUND ENGINE

The steam arm swings from the bonnet in the usual manner and carries the latch shaft in a substantial bearing, to which is keyed the knock off bar. The knockoff bar has a counterbalance of sufficient weight to assist materially in the functioning of the releasing device.

The steam valve being closed, as the steam arm moves to the right to engage the latch block, the counterweight on the knockoff bar has inertia enough to cause the latch to engage and the reversal of the steam arm further tends to retain positive engagement of the parts.

When the steam arm has carried the valve to the point of cutoff as determined by the governor, the inertia of the counterweight on the knockoff bar is reversed which reduces the strain on the governor to a very small amount, and on the return of the steam arm to the starting position of the cycle, the latch block and the latch shaft are held apart until the instant of engagement of the parts.

A safety cam on the knockoff ring is provided so as to prevent the steam valve being opened should the governor belt break. A positive closing pin on the steam arm insures closure of the valve should accident

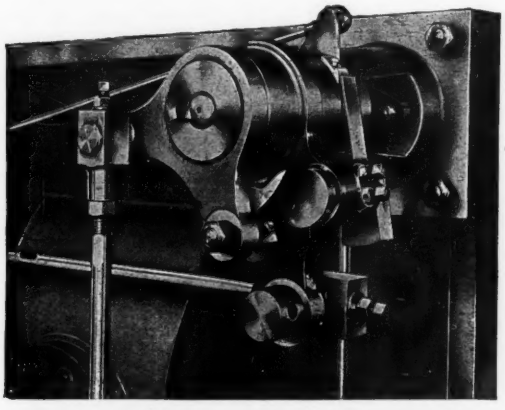


FIG. 2. BATES INERTIA GEAR ON THE CYLINDER

prevent the usual method of closure. Engagement of the latch blocks can be adjusted by a set screw to any amount from zero to abnormal limits.

On double eccentric engines, the steam levers are connected by a steam rod while the exhaust valves are operated by a wrist plate in the usual manner.

Dashpots are designed in such a manner that they will act quickly throughout the range of cutoff. They are bored to 2 diameters, the lower portion of the plunger being slightly larger than the upper portion. When the plunger is in the lowest position, the annular space above it is full of air which escapes through a needle regulating valve to the chamber below the plunger as soon as that is raised.

This is not enough to destroy the vacuum but it is enough to provide air for cushioning even at shortest valve travel, and the rapidity with which the air escaped from the space below the plunger back to the annular space above it, is controlled by the needle valve. There is no escape of air to the atmosphere, as it travels back and forth from one chamber to the other in quantities depending on the point of cutoff of the valve.

The governor is of the medium speed type with counterpoise, gagpot and safety stop, and is sensitive to slight speed variations. The piston is of the 3-piece type, with adjustable bull ring, and 2 packing rings which can be removed without removing the piston from the cylinder; the follower is held in place by bolts positively locked in place. The piston is a taper press fit on the rod and locked with a steel nut.

The crosshead is of the usual box type with the metal well distributed to resist strains, and has 2 babbited shoes held in place and adjustable on tapered slides. The pin has a flanged head and is ground in place with taper fits.

The reach rods are provided with telescopic detaching devices, to enable the valve gear to be worked by hand. In ordinary operation the rods are held together by a positive lock, which prevents all possibility of movement at that point.

The crank is a counterbalanced disk pressed on the shaft and keyed in place. The outboard bearing may be the pillow block type adjusted on a sole plate, or the pedestal type with quarter boxes and vertical adjustment.

The Bates engine is built in all combinations of cylinder arrangement and at high speeds for any pressure desired.

COOPER CORLISS ENGINE

The C. & G. Cooper Co., Mt. Vernon, O.

THE improved Cooper gravity latch Corliss valve gear is the distinguishing feature of Cooper Corliss engines, and it has been adopted as standard on all Cooper engines giving good results at both high and low speeds. It is noiseless in operation, simple and easily accessible, and of a design which permits liberal proportions and strength in the main working parts.

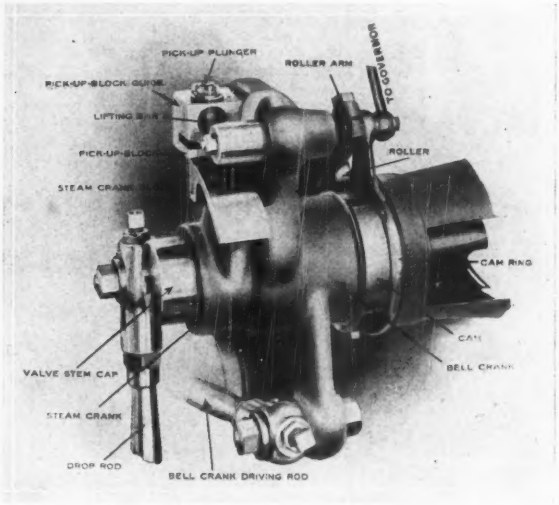


FIG. 2. COOPER GRAVITY LATCH CORLISS VALVE GEAR

The use of double ported steam and exhaust valves, thereby reducing the valve travels adds to the ease of operation at the higher speeds.

The latching or hooking up operation is performed by a pick-up plunger, through the action of gravity. The pick-up plunger is contained and operates in a guide block, and both are of case hardened steel with special provisions for taking up wear. The pick-up plunger guide block is provided with an auxiliary spring attachment which can be brought into use in-

stantly while the engine is in operation, to assist the gravity latching action of the pick-up plunger, if for any reason it should become sluggish.

Releasing action is transmitted from the knock-off cam on the governor cam ring, through a roller arm and lifting bar, to the pick-up plunger. The end of the roller arm which engages this cam is provided with a hardened roller, which is always in rolling contact on the governor cam ring. The opposite end of the roller arm, where it is joined to the lifting bar is adjustable for changing the lap of the steel block edges in hooking up, in case of any undue wearing or accidental breaking of the block edges.

Relative positions of the steel blocks on the pick-up plunger and the steam crank are such that the engaging faces of the blocks are parallel, in a radial line, extending from the center line of the valve stem. The pick-up plunger maintains this same relation to the steam crank in all its working positions, due to its fixed path of travel in the pick-up plunger guide block, so that after hooking up, the engaging faces of the steel blocks continue to remain parallel to each other up to the instant release takes place, eliminating rounding of the edges.

however, they should for any reason fail to act the steam crank is automatically closed by the mechanical engagement of the bell crank against it.

The crosshead is a steel casting provided with shoes, lined with babbit metal, and arranged with suitable means for adjustment; they are so made that they may be taken off without removing the crosshead. The crosshead pin is secured to the crosshead by a double-taper fit, and held by means of a collar at one end, and a spanner or hexagon nut at the other.

The governor is the flyball type provided with an automatic stop to shut off steam in case the governor belt fails and a weight and lever for the purpose of varying the speed of the engine while in operation.

The piston is of the center-ring type, arranged with follower and self-acting steam packing ring. An important feature of this design is that the rings can be taken off without removing the piston. In addition to the follower and self-acting packing ring, the piston is provided with bull rings which cover its entire face.

In horsepowers from 50 to 500 the girder type of frame is most commonly used, while above this to 10,000 hp. capacity the tangye bed prevails.

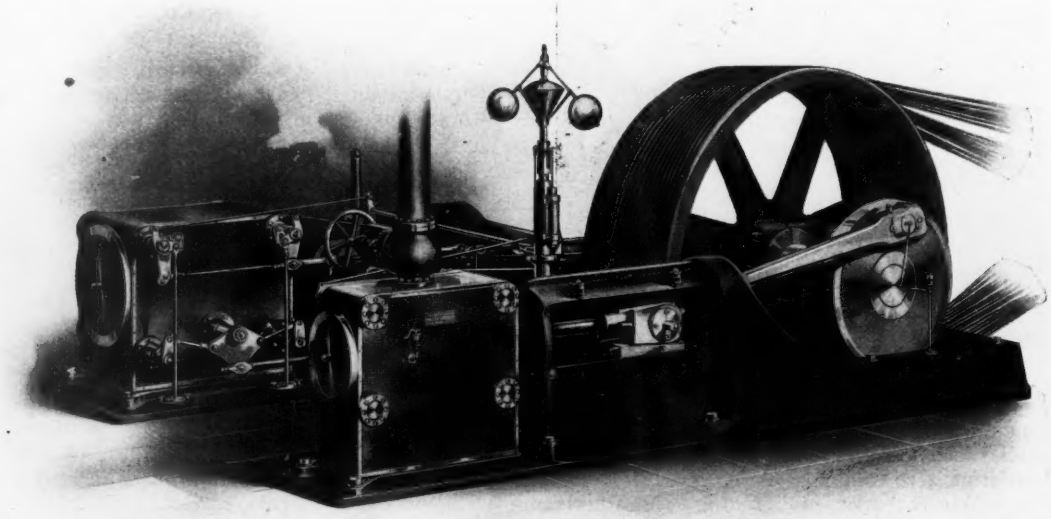


FIG. 1. HEAVY DUTY COOPER CORLISS ENGINE FOR ROPE DRIVE

Governor cam rings are located on the inner side of the bell cranks, which serves as an extra precaution to protect these working parts from injury.

A novel construction feature is the combining of the safety and knock-off cams into a single large cam, so that by the adjustment of this cam accurate equalization of the cutoffs in the 2 ends of the cylinder can be easily and quickly made, and will be maintained at all loads.

The governor cam ring is constructed to receive this single cam in a recessed joint and it is held in place, in addition, by means of a lock nut. After this equalization adjustment has been made, equal points of cutoff will be maintained under all conditions of operation, from no load to full load.

Vacuum pots are of the piston type and sealed with oil grooves, are quick and positive in their action. If,

FILER AND STOWELL ENGINE

The Filer and Stowell Co., Milwaukee, Wis.

THE Filer and Stowell Corliss engine is made with 2 general types of frames, the standard heavy duty in which the guide barrel is not supported from below, and in which the part forward of the guides, heavy and massive, is supported on a sole plate extending several inches beyond the frame itself; and the "1900" Heavy Duty, or rolling mill frame, in which the entire frame rests on the foundation, the crank case being cast integral with the frame and forming a reservoir for the oil.

Ordinarily the bosses for the carrier arm brackets are cast with the frame and stiffened with braces, and the pins pressed into reamed holes. The main bearings are of the single or double wedge quarter box

type with the adjusting wedge in front, or both sides, and the bottom shell in 2 concentric pieces as shown in Fig. 1. The standard frame, however, has the front screw adjustment, and single bottom shell.

The cylinder is cast thick enough to withstand 150 lb. pressure after 2 reborings, 12-in. cylinders being single ported, those 14-in. and above, double ported, and all port openings on cylinders 20 in. and larger are stayed with steel staybolts inside of cast iron boxes. All ports are liberal and direct, permitting rapid flow of the steam and low clearance.

The piston is of the built up type with 2 broad adjustable junk rings with which to center the piston in the cylinder. The piston is pressed on the rod against a shoulder and the rod riveted over into a large countersink.

The steam valve gear as shown in Fig. 2, is simple, and accessible for attention and operation, with leverage of the knock off bar over 3 times the leverage of the trip pin, relieving the governor of strain. A safety closing pin on the steam lever prevents the steam valve from remaining open after the exhaust valve at that end has opened.

Steam valves are driven by either a separate wrist-plate, as in Fig. 3, or by connecting the 2 steam levers by a steam rod, and connecting the forward one to the hook rod by a releasing hook.

Dashpots are set nearly flush with the top of the cylinder foundation plate, and are of the double chamber type, the cushion chamber having a graduated slot in the side which permits rapid closing of the pot until it is within a fraction of an inch, when the remaining entrained air is exhausted through a regulating valve and escapes noiselessly under the floor.

The governor is of the weighted counterpoise high-speed type, the vertical spindle of which rotates in an oil bath, on hardened steel cones, and is provided with an automatic stop which is always operative; in case of breaking of the governor belt, the governor in stopping, drops half an inch more than usual, thus throwing the safety cams into position on the steam valve gear, preventing opening of the steam valves. Each governor is also provided with an adjustable oil gagpot and a shifting weight on a bar for slight changes in speed.

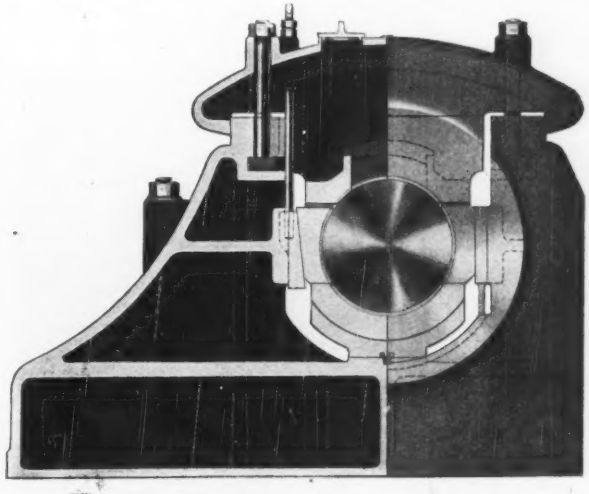


FIG. 1. MAIN BEARING OF "1900" FILER AND STOWELL ENGINE

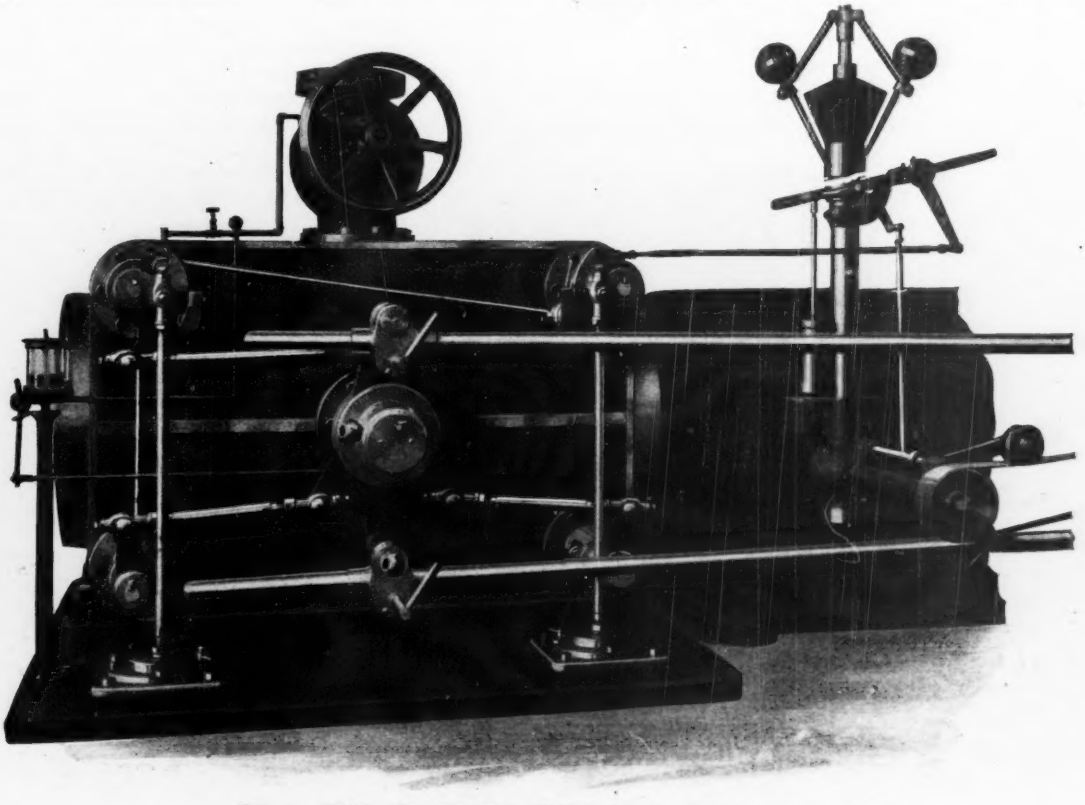


FIG. 3. FILER AND STOWELL ENGINE WITH DOUBLE WRIST PLATE

The enclosed heavy duty governor used on the

larger engines is identical in every respect with that described above, except that the enclosing vessel forms the counterpoise.

The crosshead is compact and has tapered babbited shoes adjusted by means of a single locked screw on

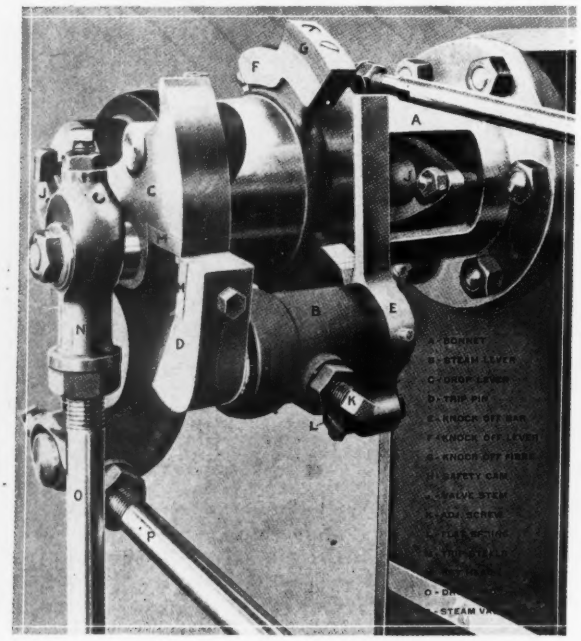


FIG. 2. FILER AND STOWELL VALVE GEAR

each. The hub to receive the screwed piston rod is tapered and braced.

The connecting rod is of the solid end type with adjusting wedges on the forward side of both pins the full width of the brasses. Cranks may be either counterbalanced, fantail, or disk type, or the plain crank, and are of special semisteel, pressed on the shaft and keyed.

HARRIS-CORLISS ENGINE

Wm. A. Harris Steam Engine Co., Providence, R. I.

THIS engine, as shown by illustrations, is of Corliss type, designed for direct connected electric service; or for any heavy duty service, with belt or rope drive, as may be required. It is built of any desired type, simple, double, or compound; for use with or without condensing apparatus; compound units are of either

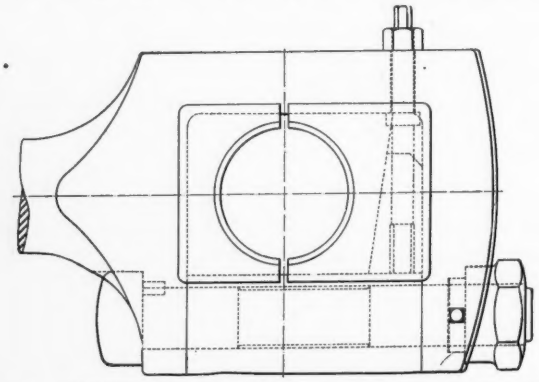


FIG. 2. HATCHET END OF HARRIS CORLISS CONNECTING ROD

tandem or cross type. For ordinary mill service it has heavy girder frame, with either single or double eccentric equipment; where double eccentrics are employed, wrist plates are entirely dispensed with, and provision is made for a long range of cutoff up to 75 per cent of the stroke. The guides in all frames, either girder or heavy duty type, are bored concentric with the centre line of the engine.

Harris-Corliss engines are designed for operation at any desired speed up to 150 r.p.m., and are equipped with Brown Patented valve releasing gear, operated entirely by gravity. The toe drops into place positively and effectively under any and all condtiions of operation and speed. The drop latch block is controlled by a lever having a roll on the end, which roll runs in

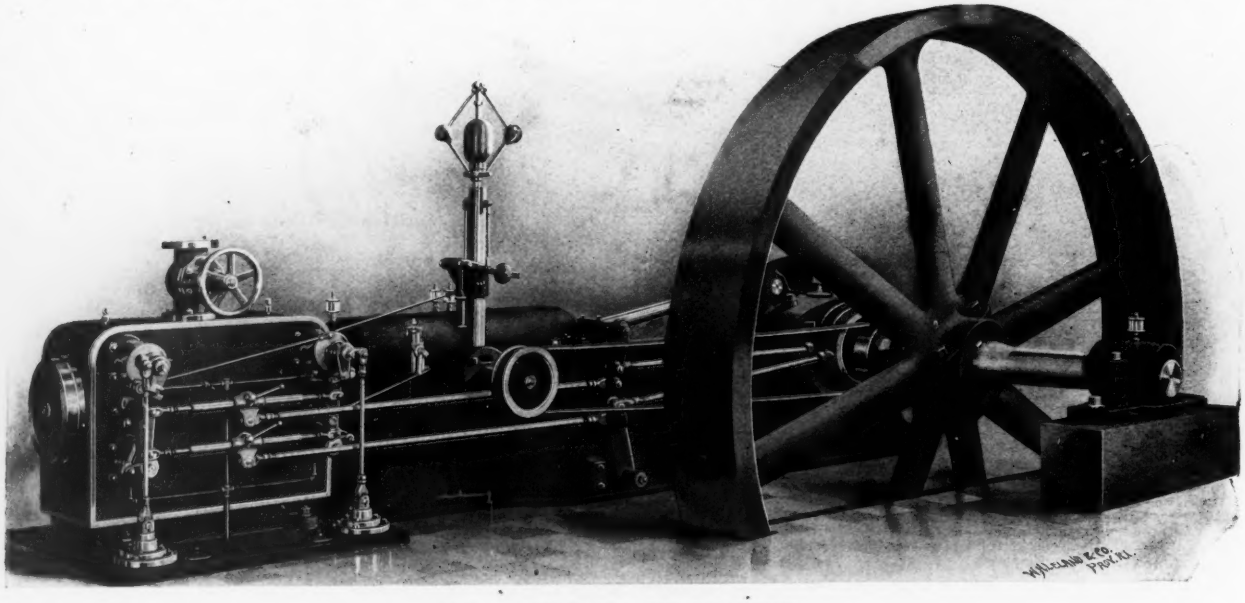


FIG. 1. THE HARRIS CORLISS ENGINE

a radial slot of such design that the engaging of the hook is always positive, while release is accomplished by the roll entering a slot of a larger radius.

The point at which this change of movement takes place is under the control of the governor, no shock or strain of any character being transmitted to the governing mechanism when the cutoff takes place. The arrangement of this valve mechanism and the regulator is such as to provide a safety device for closing the steam valves in the event of dashpots failing to operate

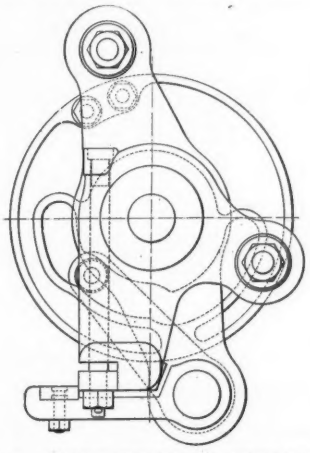


FIG. 3. VALVE RELEASING MECHANISM

or regulator belt becoming broken. The valve gear latch block and toe plates, the only wearing parts, have 8 hardened wearing edges, giving great durability.

Dashpots are of noiseless vacuum type, promptly closing the steam valves throughout the entire range of cutoff. They are arranged upon an independent iron plate, for location above the engine room floor, where they can be in view and readily accessible at all times.

The governor is of high speed Porter type, with heavy balls and counter-poise, and, running at a speed of 225 r.p.m. gives close regulation under all conditions of load.

The connecting rod is of solid end type, with wedge adjustment at each end; and the design is such that the center to center of boxes is maintained even when the boxes become worn. For large engines, the hatchet end with one side removable is used as in Fig 2.

The crosshead is of heavy box pattern design, having removable and adjustable shoes, filled with babbit metal, and turned to an exact fit of the bored guides, adjustment for wear being made by means of concealed wedges.

The piston is forced on its rod by hydraulic pressure, against a shoulder, and a steel retaining collar at the back end of the rod, fitted into a recess in the piston head, adds to the strength and security. The junk ring with the adjusting screws for the centering of the piston extends over the full width of the piston and follower, and is grooved to receive a packing ring of sectional type, having bronze plates with spiral springs at the joints of the segments. With large cylinders, the piston junk ring is grooved and filled with antifriction metal.

THE HAMILTON CORLISS ENGINE

The Hooven, Owens Rentschler Co., Hamilton, Ohio

THE Hamilton Corliss engine is built in both girder and heavy duty types, single and double eccentric, to suit requirements, the girder frame being used mostly on engines for mill work and the heavy duty type for electrical installations and rolling mill service.

The girder frame is designed in such a manner that there is a heavy stiffening rib reaching from the cylinder to the bearing, and ordinarily is fitted with V guides. It has the lower half of the main bearing cast integral with the frame, and babbited in place.

The heavy-duty frame is cast in one piece, the metal being carried around and underneath the crank disk and the guides are bored. The lower bearing shell rests in a bored seat which permits removing the bearing when released of the weight of the shaft, and quarter boxes have full width wedge adjustment. An oil groove surrounds the entire frame at the floor line.

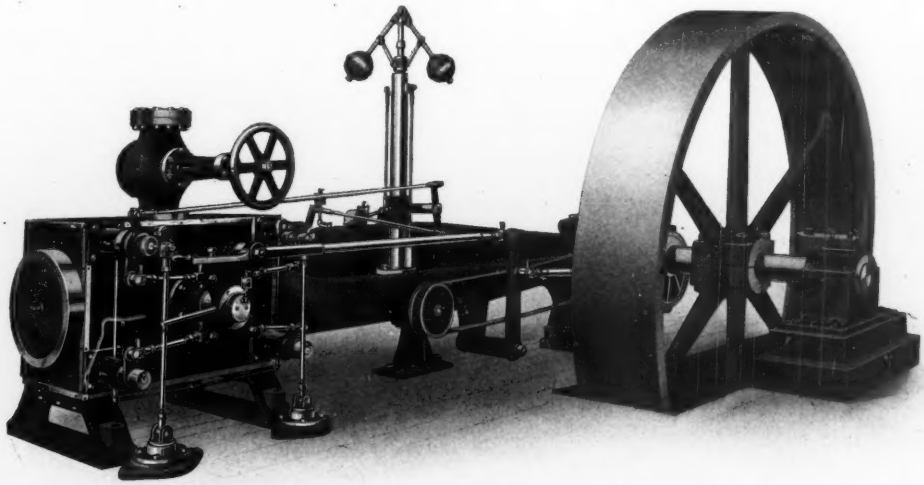


FIG. 1. HAMILTON CORLISS GIRDER FRAME ENGINE

Depending on the nature of the service, the outboard bearing may be either the standard pillow block with separate sole plate, with side adjustment only, or the heavy pedestal type with full wedge adjustment.

Cranks of either gray cast iron or semisteel are of

counterbalanced disk type with open hearth forged steel crankpin forced in by hydraulic pressure and riveted over.

The cylinder is cast from a special mixture of semi-steel of high tensile strength, with double ports liberal and direct, to prevent wiredrawing.

Steam valve gear is of the releasing gravity type and operates noiselessly owing to the absence of

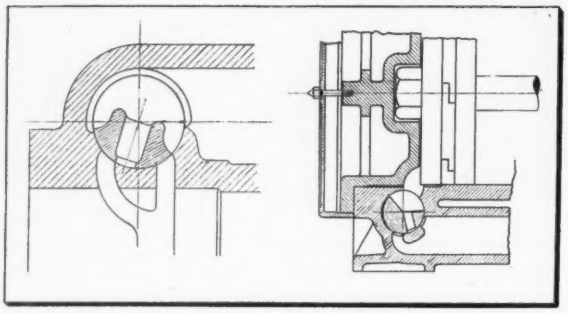


FIG. 2. HAMILTON STEAM AND EXHAUST VALVES

springs to assist in closing the latch, this being accomplished by gravity alone. The latch and cam lever are steel forgings, tripping being accomplished by a steel roller on the latch striking the knockoff cams which are under control of the governor. The entire steam valve gear is compact and accessible which permits operation at a high speed.

Dashpots are of the single chamber vacuum type and are noiseless under all ranges of load, the drop rod being attached by means of a ball and socket joint. The governor is of the medium speed type with weighted counterpoise, and is equipped with an overspeed safety stop as well as a safety device which prevents operation of the steam valves in case of breaking of the governor belt.

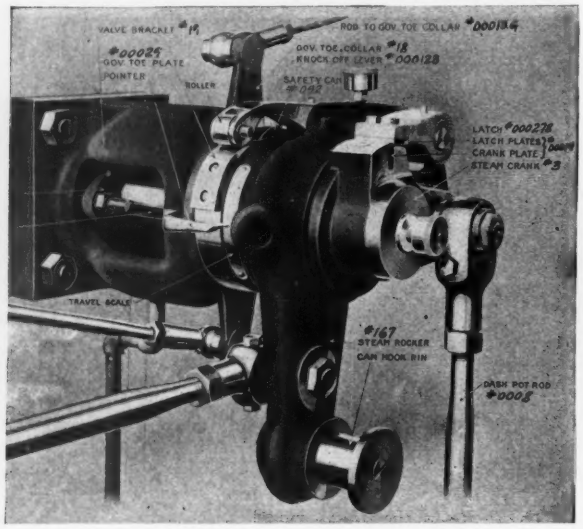


FIG. 3. THE HAMILTON STEAM VALVE GEAR

The connecting rod is of the solid end type having bronze boxes and full width wedge adjustment, by means of adjusting screws located top and bottom at each end of the rod. The crosshead is an annealed steel casting for all but the smaller sizes, having adjustable babbit lined shoes and a forged carbon steel crosshead pin, made a double taper fit with a ground joint, and held in by a flanged head bolted to the crosshead.

A heavily ribbed box type piston is used with spider, bullring, follower, and Harris & Babbitt sectional ring packing. The piston has liberal bearing surfaces and is a pressed taper fit on the rod, locked with a nut.

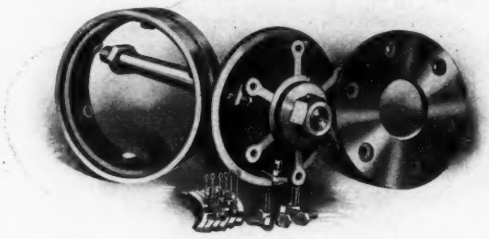


FIG. 5. PISTON DISMANTLED

The heavy globe type throttle valve has liberal passages for the steam, and a bypass valve which is operated by the main stem by slightly turning the hand wheel.

MURRAY-CORLISS ENGINE

Murray Iron Works Co., Burlington, Ia.

THE Murray Corliss engine is built in practically all sizes with girder frame well proportioned and amply strong to withstand ordinary usage; with tangye, also known as the heavy-duty frame, a massive single casting embracing the main bearing, and resting entirely upon the foundation, to which is bolted the bored guide supported by a separate pedestal; and with rolling mill frame of such design that it has a bearing upon the foundation its full length, and adapted to withstand the most severe service. The latter has a bearing which rests upon an adjusting wedge by means of which the shaft can be kept perfectly level. Quarter boxes are adjusted by massive bolts with fine thread. The entire frame is surrounded by a retaining flange which catches all oil that may splash out, thus preventing it from disintegrating the masonry.

Steam enters the cylinder through one large port of liberal area, the double port feature being secured by a steam valve of special design. Exhaust ports are double and of ample area to insure minimum back pressure. The exhaust chamber is cast in the usual way, with an air space between it and the cylinder barrel.

The Murray high-speed ball-bearing governor operates at a speed of 225 r.p.m. which makes it quick to adjust itself to any change of load. The counterpoise has a small space in the upper part which can be partially filled with shot and the speed of the engine thus brought to exactly the desired number of revolutions. All governors are provided with automatic safety stop; on engines used to operate electric generators in parallel, a shifting weight device permits slight changes in speed while the engine is in operation, in order to parallel the electrical units.

Two types of pistons are made, a solid type with snap or built-up packing rings and a built-up type with spider, junk ring, and follower and with a packing ring set out with helical steel springs. Pistons are pressed onto the rods with hydraulic pressure and locked by means of a jam nut, which in turn is also locked, piston and rod being turned up afterward.

The piston rod is screwed into the crosshead which is well proportioned and has a tapered hub which distributes the stresses due to the thrust of the piston. Babbited tapered shoes provide adjustment to take up for wear, and to preserve the alinement of the piston rod in the guide barrel.

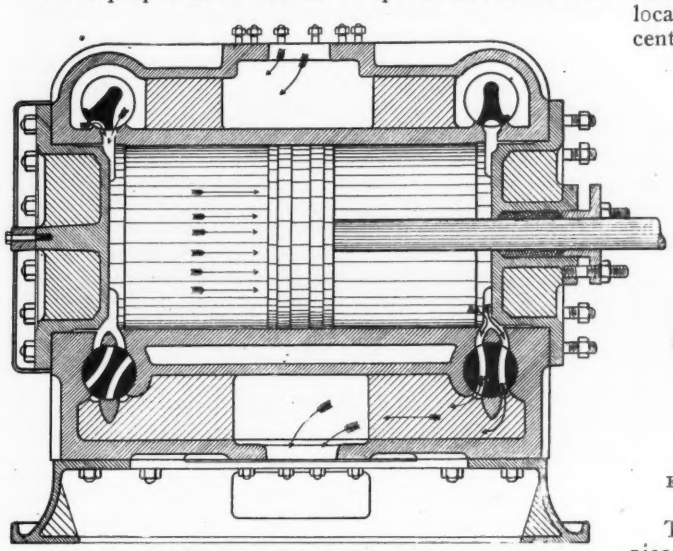


FIG. 1. SECTION THROUGH MURRAY-CORLISS CYLINDER

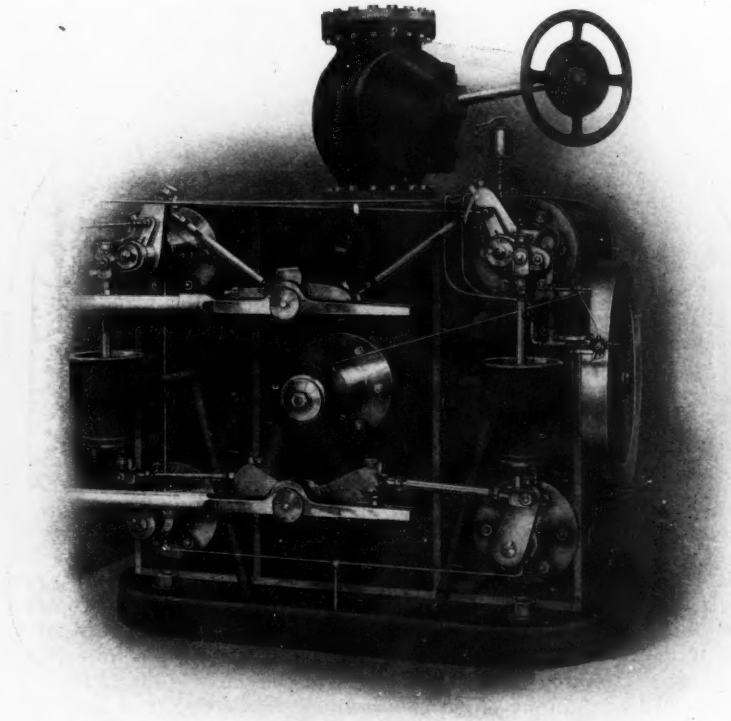


FIG. 2. ARRANGEMENT OF MURRAY-CORLISS VALVE GEAR

Dashpot plungers are turned, ground and scraped to a fit in the pot, without leathers, and are attached to the drop rods by ball and socket joint permitting free operation.

The solid forged type of connecting rod is used, slotted out to receive the boxes, with full width wedges located so as to maintain the distance from center to center of pins.

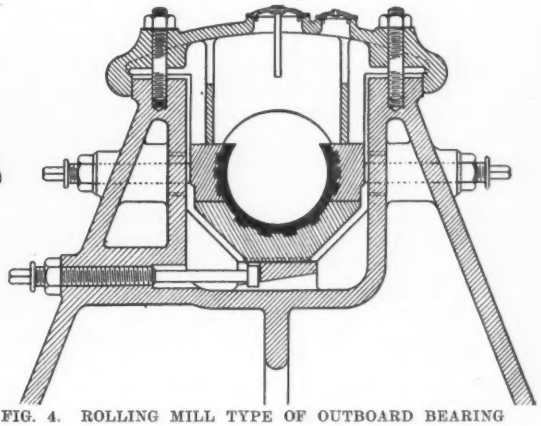


FIG. 4. ROLLING MILL TYPE OF OUTBOARD BEARING

The pedestal outboard 4-piece bearings and the 2-piece pillow block are provided with an adjusting wedge so that the shaft can be raised or lowered to preserve alinement.

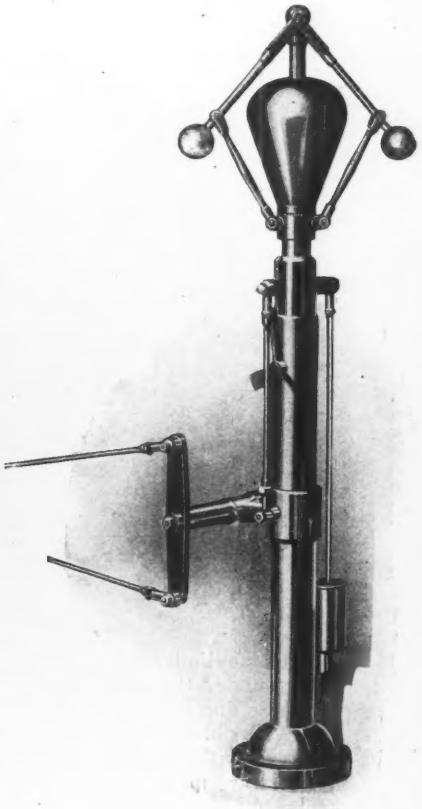


FIG. 3. MURRAY GOVERNOR WITH SLIDING WEIGHT FOR VARYING THE SPEED

The Murray-Corliss engine is built in all of the usual large sizes and small engines ranging in sizes from 8 by 18 in. to 11 by 18 in., have also been placed upon the market.

MESTA CORLISS ENGINE

The Mesta Machine Co., Pittsburgh, Pa.

THE frame of the Mesta Corliss engine is in one piece with a liberal bearing on the foundation throughout the entire length. It is headed to catch any oil that may find its way down the side of the engine.

Bearings are of the 4 or 5-piece type, the latter having the bottom shell in 2 pieces, the inner one of which is turned concentric with the shaft to facilitate its removal. The quarter boxes are adjusted by wedges having a bearing the entire width of the journal, the wedge bolts projecting above the main bearing cap.

Two eccentrics are used to operate the valves. Each pair of valves is connected to the driving levers by a rod, and the forward lever operated by the eccentric.

The steam valve gear has the drop lever located either at the extreme end of the stem, or just inside of the outboard stem bearing, as desired. In either case the construction is such that ease of operation and reliability are the prime considerations.

In the Corliss engines for 3 high mill service, arrangements for reversing are provided in case the engine is stalled by a "sticker." The valve gear may be quickly disconnected from the ecentrics, the exhaust valves centered and the engine reversed by means of a special valve which admits steam on one side of the piston and opens the other side to exhaust.

On large engines, the steel cone piston with one sectional packing ring is used. The weight of the piston is carried by the crosshead guides, preventing wear in the cylinders.

The piston is a press fit on the rod and is capped by a steel nut. The rod may screw into the crosshead or have a taper fit and be secured by a key passing through the crosshead and the rod.

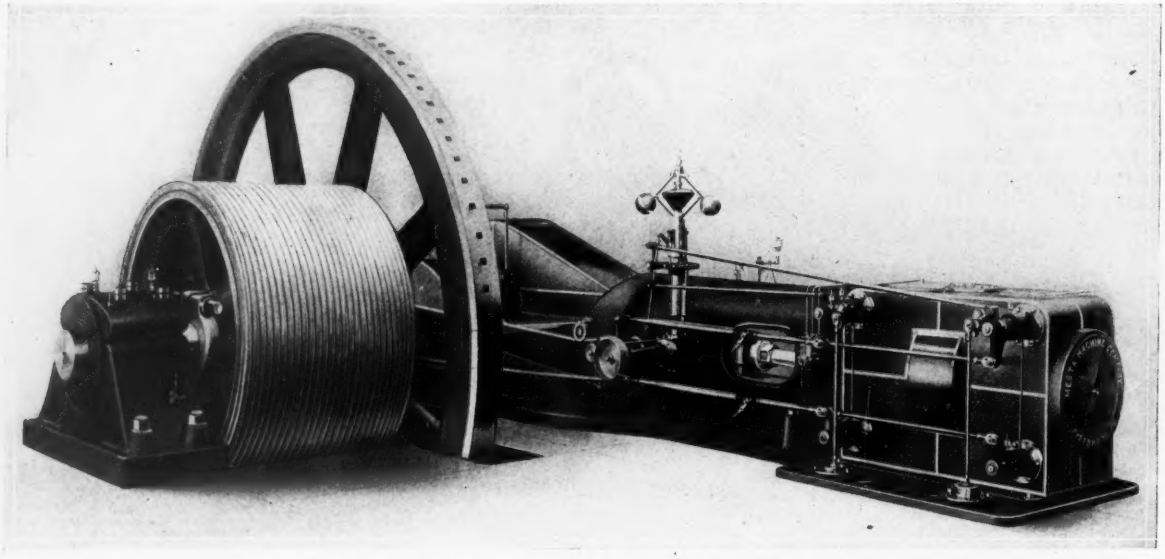
On large engines the throttle valve is designed with the valve stem on an angle so as to bring the hand wheel within easy reach of the operating floor.

Besides building Corliss engines, simple, tandem, cross compound, or with any other combination such as twin tandem, or horizontal-vertical, the Mesta Machine Company builds a great variety of direct connected and geared reversing engines, with both bored and bar guides, and with rotary or piston valves.

TWIN CITY CORLISS ENGINE

Minneapolis Steel & Machinery Co., Minneapolis, Minn.

IN the Twin City Corliss girder frame, a substantial pedestal supports the main bearing and another the forward end of the guides which are bored, the carrier arm pin being attached to the guide pedestal. A heavy rib extends from the bearing to the cylinder, making the frame very rigid.



MESTA CORLISS HEAVY DUTY ENGINE FOR ROPE DRIVE

The entire cylinder rests on a sole plate which extends out under the valve gear and is also bolted to the frame. The sole plate for large sizes takes the form of a well ribbed box frame, about 8 in. in depth which is filled with concrete when in place.

Governors are made in several designs to meet requirements but are generally of the medium speed flyball type with counterweight, and are provided with safety stop devices and control cylinders if used on pumping or compression machinery.

Dashpots of the double chamber type, the pots scraped to fit the turned and ground plunger, may be located on the side of the cylinder proper, or on the sole plate, or bolted to the side of the box frame under the larger cylinders.

In the heavy duty engines, both a one and 2 piece frame are made, the former being a continuous frame with liberal flanges on the bottom where it is supported by the foundation. In the 2-piece frame, the guide barrel is a separate casting heavily ribbed top and bottom, bored and faced at one setting, and bolted to a frame which is continuous from the guides forward, and rests upon a flat surface of the foundation.

All main bearings are of 4-piece design with wedge adjustment to the quarter boxes, the adjusting bolts passing up through the cap. On the wheel side of the frame, a trough is cast on the side with a cored hole through the frame to the crank case for the passage of the oil which drains out of the bearing.

Under the cylinders, which are double ported, is a liberal plate forming a substantial support for the cylinder and the dashpots which are of the double chamber type.

On single eccentric engines, a circular wrist plate is used and with double eccentrics a quadrant, the effect being that of a single plate, both carrier arms being attached to the same pin or shaft, which is attached to the frame by means of tap bolts.

In the steam valve gear which is peculiar to the Twin City Corliss, a small coil spring in a recess inside the bearing of the crabclaw, provides a positive and quiet means of contact of the engaging devices.

The governor is of the center-weight slow-speed flyball type, which is not affected by any thrust from the disengaging devices of the valve gear, and which regulates within a close margin. It has a positive automatic safety stop.

The piston is made up of spider, male and female junk rings, adjustable for centering the piston, steam packing ring set out with flat leaf springs, and a follower plate held on by cap screws. The spider is pressed on the screwed end rod and riveted over.

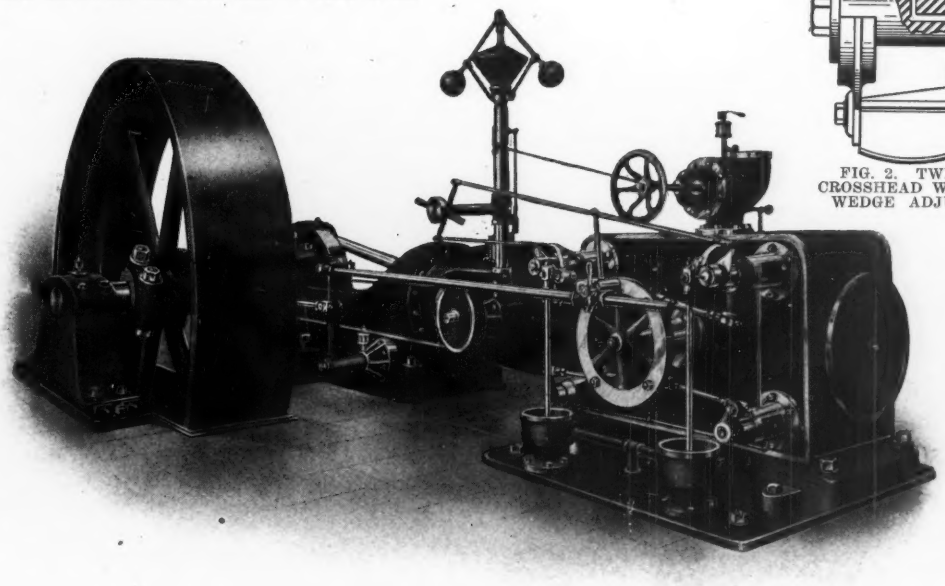


FIG. 1. TWIN CITY HEAVY DUTY CORLISS ENGINE

The crosshead is of cast iron or steel with a liberal hub, threaded to receive the piston rod, and has babbit lined shoes positively held in place by cross wedges by means of which the shoes can be adjusted to any position and then locked by 4 through bolts at the corners. A taper ground joint, flange head crosshead pin is provided which is locked in place by a nut on the inside.

A solid end connecting rod has bronze boxes, the one at the crank end being babbit lined. The adjusting wedges are both ahead of the pins, and are full width of the boxes and are adjusted by a through bolt. Disk crank with a well designed enclosed counterbalance is used.

For an outboard bearing a pedestal designed after the main bearing of the engine it is to accompany, is used. Screws are provided for adjusting the bearing to keep the shaft in line with the engines as well as to provide a centering device for direct connected units.

NAGLE CORLISS ENGINE

The Nagle Corliss Engine Works, Erie, Pa.

THE girder frame of rigid design and symmetrical appearance, is cast in one piece with liberal pedestals under the bearing and under the forward end of the bored guides, the former having a raised edge to collect all the oil which drains from the main bearing. The end of the guides is well braced to the frame which has a substantial web along the rear side extending from the cylinder to the bearing.

The heavy duty frame, Fig. 5, has a continuous bearing on the foundation and is designed for the heaviest service, having bored guides and an oil pan under the crank cast integral with the frame, and a 4-piece babbit-lined bearing with wedges for adjusting the side shells, the bolts of which project above the bearing cap.

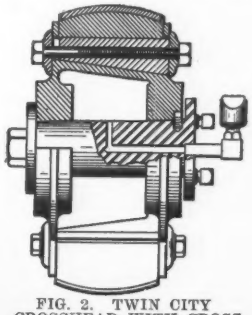


FIG. 2. TWIN CITY CROSSHEAD WITH CROSS WEDGE ADJUSTMENT

Bored ports for the valves are located as close to the bore of the cylinder as possible, the valves being turned, ground and fitted by scraping the seats.

The valve gear is of Reynolds type, the valves operated by single or double eccentrics, and wrist plates to correspond. The releasing device as used on the hook rods consists of a heavy bolt driven into the wrist plate and fastened by a nut, and through the head of which is drilled a hole at the 2 angles to correspond to the extreme positions of the wrist plate.

The detaching device is first put in place on the wrist plate pin, and then the hook rod run through it. A taper plug on top of the detaching device is actuated by a spring which assists the plug to enter a corresponding hole in the rod at the proper point, when a lever on the side is turned in such a manner as to clamp the device to the rod and relieve the strain on the spring pin.

For the smaller sizes of engines, the piston is cast in one piece, bored a taper fit and pressed on the piston rod, after which rod and piston are machined.

Two sets of steam packing rings are used, each being in 2 rings and sectional. The outer ring of each set is L shaped in cross section while its mate fits into the corner, and both are scraped to a perfect fit. Very small holes are drilled from each set of rings to the side of the piston to which that set corresponds, through which steam pressure is admitted to press the rings outward enough to form a steam tight joint.

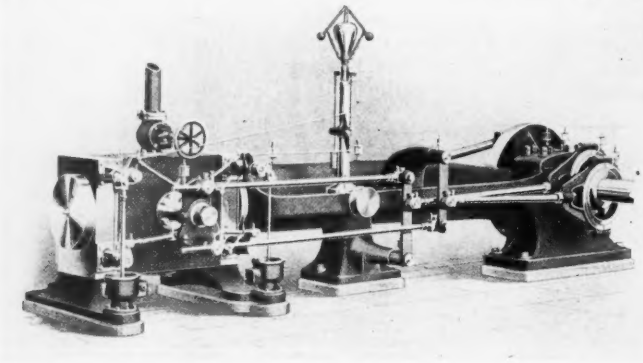


FIG. 1. NAGLE GIRDER FRAME CORLISS SPECIAL ENGINE

For the larger sizes of pistons, a cored spider is pressed on the rod and machined, after which a bull-ring the entire width of the piston is put on which has but one set of sectional packing rings of the same construction as the ones described, only that they are held out to place by flat springs. On each side of the steam ring is a broad ring of antifriction metal.

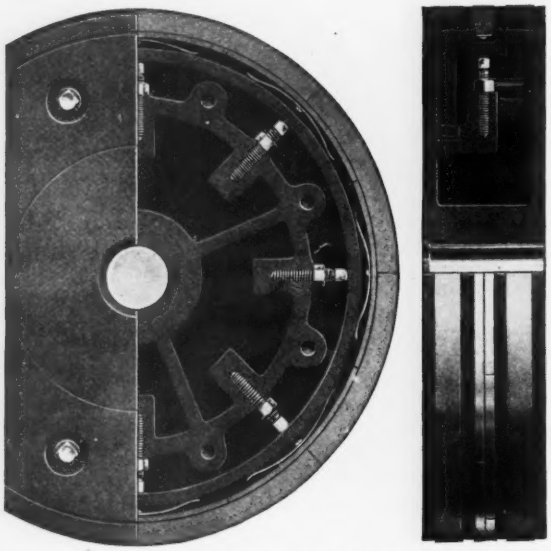


FIG. 2. NAGLE PISTON FOR LARGE ENGINES

The governor is of the high speed weighted Porter type and runs on hardened steel balls in a case hardened bearing. The weight, or counterpoise, is cast with a cavity for adding or removing shot to change the speed of the engine within small limits, has an oil gagpot to steady the control, and an automatic safety stop.

Dashpots are double chambered, cushion-and-vacuum design and are attached to the drop rods by a ball-and-socket joint. They are fastened to an extension of the cylinder feet, or to the cylinder foundation plate in the usual manner as the case may be.

The crosshead of well braced box design has a cone-shaped hub into which the piston rod is screwed and liberal babbit-lined shoes tapered and adjustable,

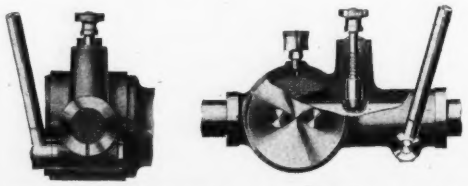


FIG. 3. NAGLE REACH ROD DETACHING DEVICE

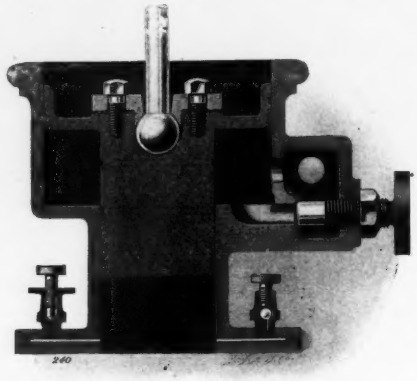


FIG. 4. NAGLE DASHPOT

and having a through bolt for the purpose of locking them in addition to the double jam nut on the adjusting screws.

The steel crosshead pin is a ground taper fit in the crosshead and keyed to prevent turning. The pin has a large hole drilled through it endwise, in which a finished bolt is placed which holds the pin in place by

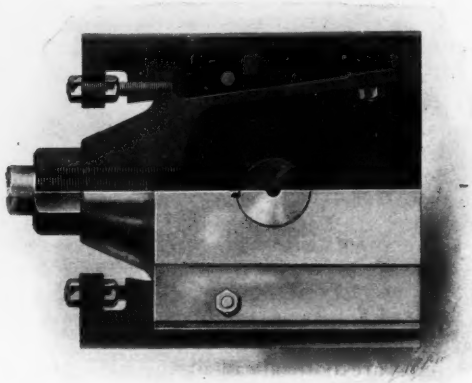


FIG. 6. NAGLE CROSSHEAD SHOWING PIN IN NORMAL POSITION

means of a large cupped washer over the small end of the pin. To remove the pin, place the washer on the opposite end and tighten up on the bolt which will jack the pin out of place.

Where an outboard bearing is used, it is usually of the pillow-block type in halved with a wedge for vertical adjustment, and screws for horizontal adjustment.

To meet the demand for an economical engine of small design, the builders of the Nagle Corliss engine have brought out a small girder engine identical in every respect with the larger ones, having cylinders ranging from 8 by 16 to 12 by 30 in., and developing from 17 to 110 hp. at economical points of cutoff.

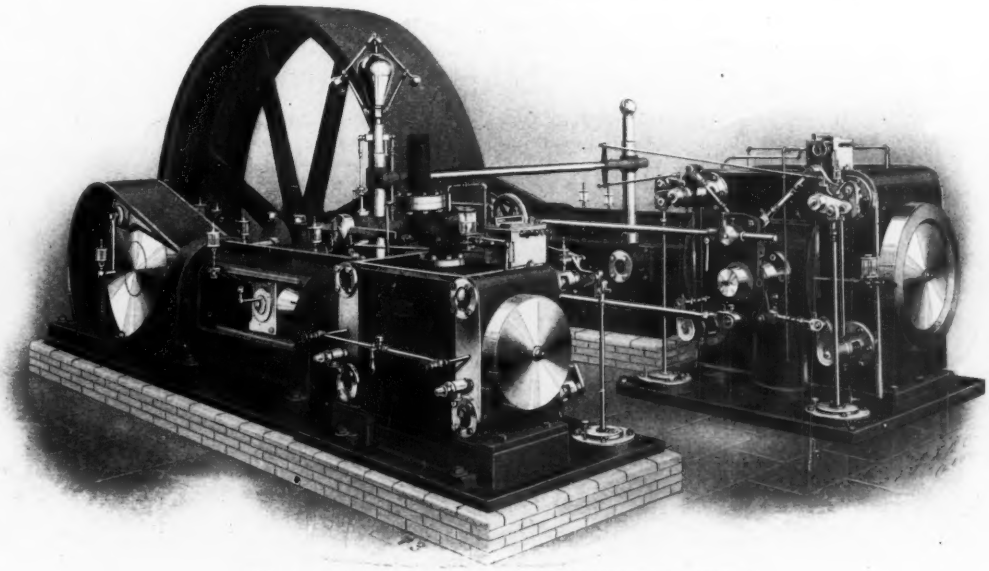


FIG. 5. NAGLE HEAVY DUTY CROSS-COMPOUND ENGINE

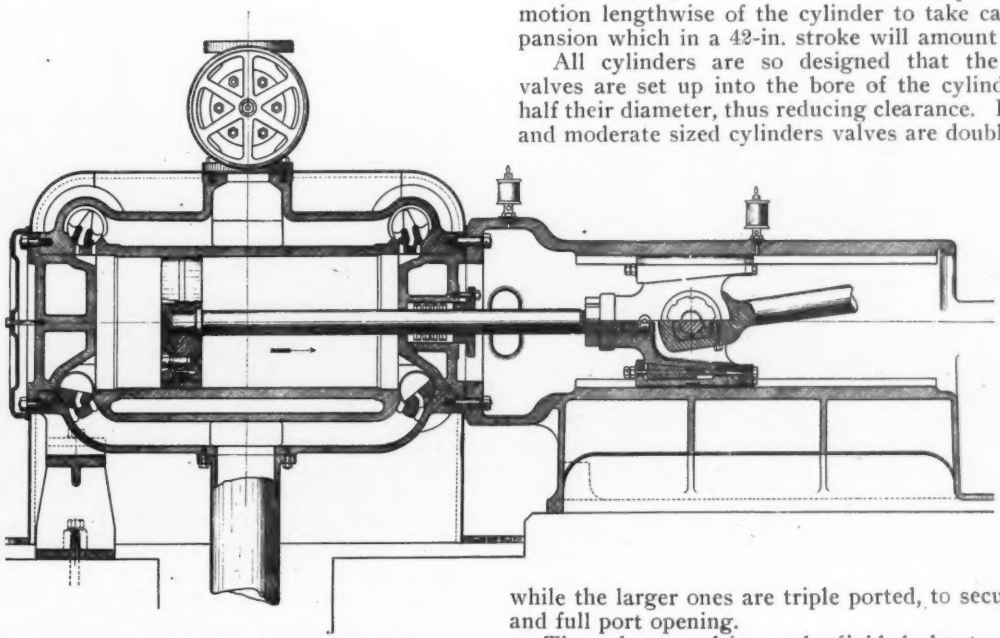


FIG. 1. SECTION OF RICE AND SARGENT ENGINE

All types are made in simple, tandem or cross-compound arrangements for belted or direct connected service.

RICE AND SARGENT ENGINE

Providence Engineering Works, Providence, R. I.

THE sectional view shown in Fig. 1 fully illustrates the general arrangements of the essential parts which go to make up the Rice and Sargent Corliss engine, which is built in all cylinder arrangements called for by modern practice. The heavy duty type of frame is used almost exclusively, the bed resting on the foundations throughout its length and carrying the crank end of the cylinder. The rear end of the cylinder is supported by a foot resting in fitted guides which hold it fast sidewise and vertically but permit motion lengthwise of the cylinder to take care of expansion which in a 42-in. stroke will amount to ½ in.

All cylinders are so designed that the exhaust valves are set up into the bore of the cylinder about half their diameter, thus reducing clearance. For small and moderate sized cylinders valves are double ported, while the larger ones are triple ported, to secure early and full port opening.

The valve travel is evenly divided about a vertical line, so that even after wear the valve will tend to fall to its seat which is directly underneath. Exhaust valves are so hollowed out that the piston may be drawn over them out of the cylinder without remov-

ing the valves. Valve stems have a collar on the inner end to take the steam thrust and form a metallic joint with the bonnet, and bear in bushings at both ends of the bonnet.

The valve gear is of special design with gravity engaging device positive in its action, so that no springs are required. By referring to Fig. 2, it will be seen that the cutoff occurs when the cam lever passes through the 2 hardened steel rollers, J J, which are under the control of the governor from 0 to ¾ stroke. As the leverage of the cam lever is about 4 times the length of the toe C, there is practically no strain on the governor, and as the governor is of the Rites inertia type the closest regulatioin is possible.

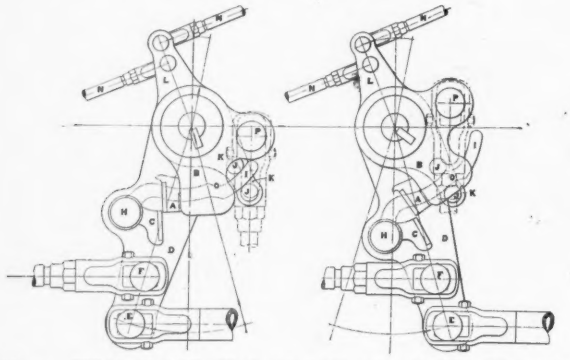


FIG. 2. STEAM VALVE GEAR OF RICE AND SARGENT ENGINE

Connections to the governor make it possible to compensate for inequalities in cutoff, and low-pressure cutoff can be set to vary the load distribution in any way desired, receiver pressure remaining constant or rising as the load increases. A speed limit operated from the crosshead, independent of the governor insures against excess speed.

Covered dashpots are set flush with the plate, and are spring actuated on speeds up to about 125 r.p.m., about which vacuum is used especially for extremely early cutoff.

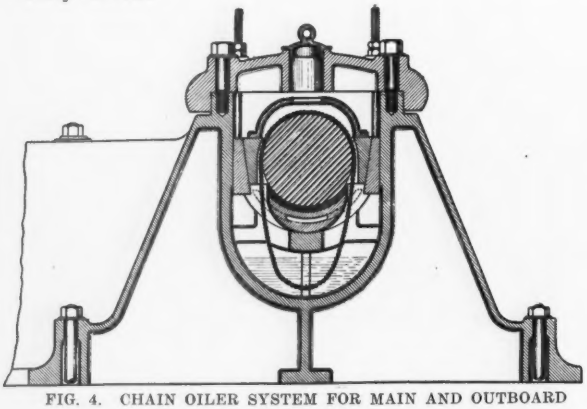


FIG. 4. CHAIN OILER SYSTEM FOR MAIN AND OUTBOARD BEARINGS

The disengaging clutch fully illustrated in Fig. 3 is of the telescopic tube type, operated by a single movement, easily adjusted and can engage only at the proper point.

Pistons have a 2-part junk ring the full width of the piston, with crank end portion carried by centering screws so that follower and head end part may be removed to reach the packing rings without disturbing the piston adjustment. The follower is held in place by Norway iron studs necked down in clearance holes and riveted on the opposite side of the piston, with inset nuts to hold the follower. After the piston is pressed up against the shoulder of the rod, the steel collar in a recess locks it securely in place.

The valve gear is operated direct from the eccentrics, as shown in the illustrations, quick opening and closing of the exhaust valves being secured by means of an interposed link actuated by a bell-crank.

On all throttles of 7 in. and larger, a pilot bypass valve is incorporated as part of the main throttle. It

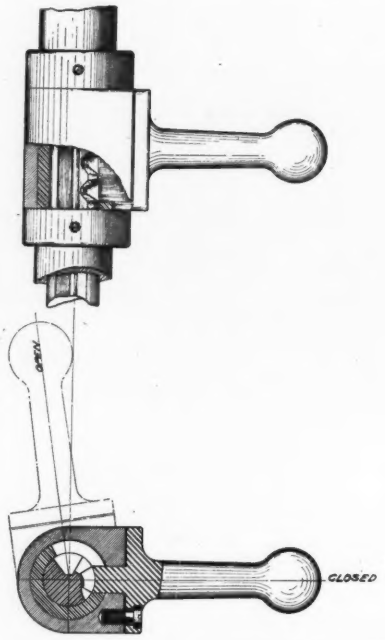


FIG. 3. DISENGAGING CLUTCH ON REACH ROD

is opened with the first movement of the stem and can be used to warm up the cylinder, and also to equalize the pressure on both sides of the main valve.

The main shaft journals, and pedestal outboard bearings, are all arranged for continuous chain oilers as shown in Fig. 4. These bearings have rising wedge adjustment on both sides, the lower side circular allowing movement to maintain alinement, and the larger sizes arranged for water cooling.

MONARCH CORLISS ENGINES

The H. N. Strait Mfg. Co., Kansas City, Kans.

THESE engines are built in girder frame, heavy duty and rolling mill type. The frame and guide sections are cast separate and bolted together, and the subbase extending under both cylinder and guides is bolted to the main frame.

The engines are made with either single or double-ported valves, and also single or double eccentrics. Compound engines are always furnished with double eccentrics, on the low-pressure cylinders, and compound noncondensing engines are made with double eccentrics on both cylinders.

Main bearings are made with a bottom section and quarter boxes, and have wedge adjustment controlled

by screws through the cap; the outboard bearings of the simple belted engine are adjustable, resting on a cast-iron sole plate.

Heavy duty engines are similar to the rolling mill frame engines, with the exception of the sub-base under the cylinder and the guide. The guides on the heavy duty engines are made with a sub-base which rests on the foundation, and the cylinders are mounted on legs which extend out under the dashpots.

Girder frame engines are made only in the small sizes, and are of the usual design, with a girder extending from the pillow block to the cylinder, and with a support under the guide. Rolling mill and heavy duty engines are furnished with crank disks, and girder frame engines with a regular crank arm. The connecting rods are made with solid ends, cut out for the boxes with wedge adjustment.

Dashpots are made of 3 main sections, a vacuum chamber, cushion chamber, and the plunger. The cushion and vacuum chambers are bolted together, and the vacuum chamber is bolted either to the sub-base or to the legs under the cylinder.

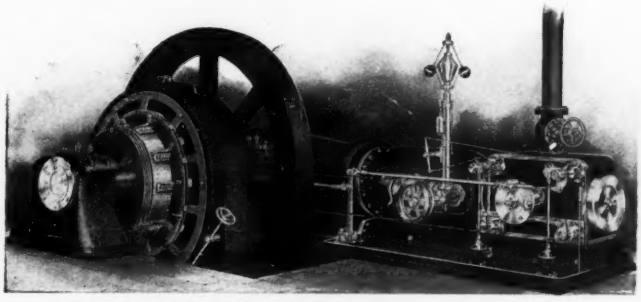


FIG. 1. ROLLING MILL TYPE MONARCH CORLISS ENGINE

THE VILTER ENGINE

The Vilter Mfg. Co., Milwaukee, Wis.

GIRDER or heavy duty type frames are furnished, the former a single casting, the latter with heavily ribbed guide barrel and pillow block separate, joined by heavy bolts, through a male and female joint. The pillow block has a wide bearing for a continuous base with holes clear through the box section; it is fitted with quarter boxes having side adjustment and has a top feel hole through cap and box. The rolling mill frame is in a single piece with continuous base under slide and bearing.

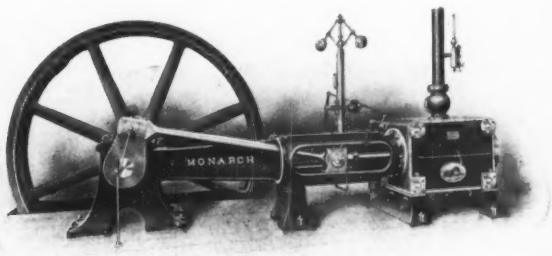


FIG. 2. MONARCH CORLISS ENGINE WITH GIRDER FRAME

Both cylinder and valve chambers are counterbored, permitting of reboring without disturbing the fit of heads and bonnets.

Pressed on to the steel crankshaft is an oval or disk crank according to the type of engine, and the crankpin is pressed in and riveted.

For the outboard bearing adjustments, a wedge vertically and by set screw sidewise, are provided in the sole plate.

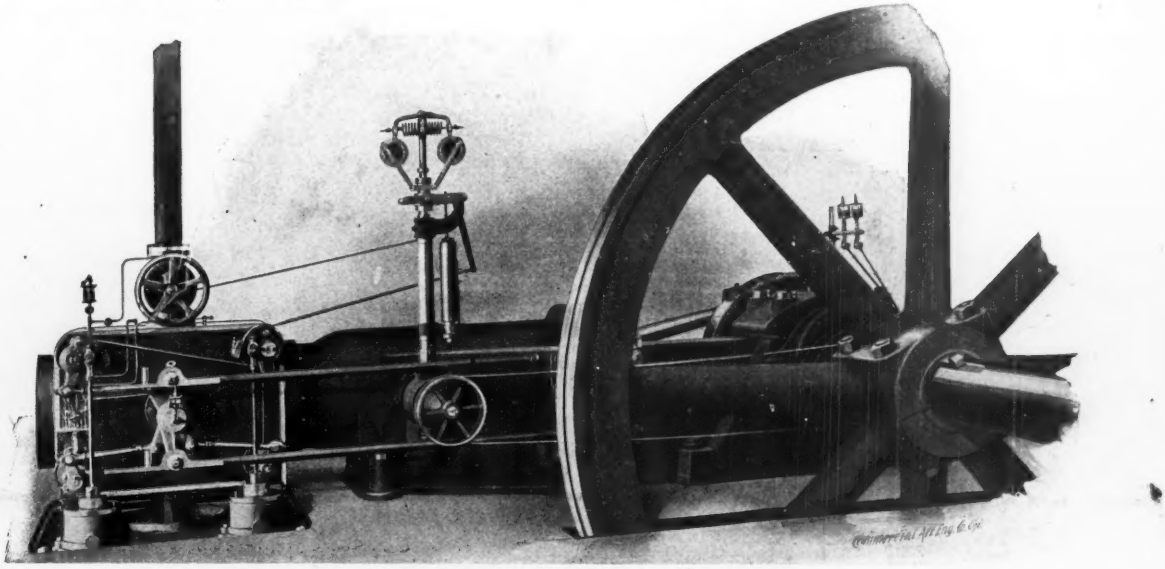


FIG. 1. VILTER ENGINE WITH HEAVY DUTY FRAME

The guides are bored and the crosshead shoes turned so as to permit of the crosshead adjusting itself to the guide, adjustment of the crosshead shoes being by wedges, which hold the shoes from moving endwise on the croshead.

Hooks of the releasing gear are of heavy cast steel forging, with hardened and tempered steel plate wearing surfaces, interchangeable on 8 sides.

The hook knockoff bars are keyed to the valve hook stems, and so arranged that they will work with-

out the aid of springs; springs are, however, attached as a safeguard, in case the edges of the plates wear. Dashpot cranks have square hardened steel trip-plates, also interchangeable on 8 sides.

Steam arms have automatic closing pins to press down the valves in case of sticking, and are supplied with hook adjusting screws to adjust the hooks, to catch properly the dashpot cranks.

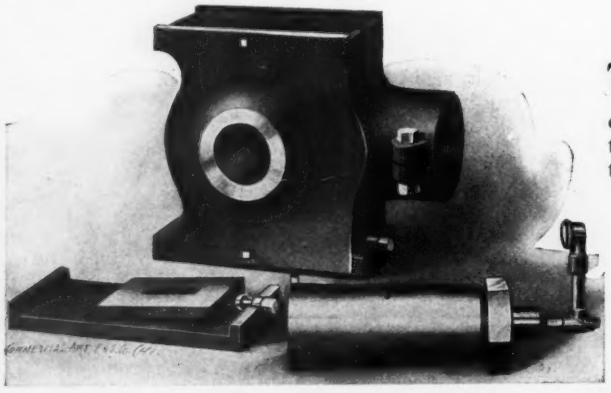


FIG. 3. VILTER CROSSHEAD AND PARTS

Dashpots are connected to the drop rods by ball and socket joints, and require only one adjusting screw for each. Plungers work with minimum lift on the inside, hence are absolutely dust proof. Oiling is accomplished by 2 oil plugs on each dashpot. Ball check valves release the superflous air.

For regulation to within 3 per cent, the high speed flyball governor is used, having a regulating weight by which speed is controlled. For close regulation the Tolle governor, as seen on Fig. 1 is used. The latter can be adjusted for varying speed over a 7½ per cent range while the engine is running and is therefore useful where alternators are to be brought into step.

The piston rod is fitted to the spider, pressed in by hydraulic pressure and secured by a steel nut. The piston has self-adjusting piston packing, held in position by 2 bull rings, and set out by flat steel springs, the joint in the spring ring being closed by a brass keeper. Bull rings are arranged with flanges overlapping the spider and follower, to maintain the full wearing surface on the cylinder, and have Allan metal rings to take the wear.

screws. The piston rod end is threaded and partially split, having lugs and bolt by which the rod is clamped into the crosshead.

The crosshead pin, turned taper at both ends, is held in position by a large nut, the end of the pin extending beyond the nut to receive the oiling arrangement for the journal.

WATTS-CAMPBELL ENGINE

The Watts-Campbell Co., Newark, N. J.

THIS engine is manufactured to meet a great variety of services, with the regular girder frame, the heavy duty frame and the rolling mill frame; double eccentrics are used, if the nature of the service is such as to require them.

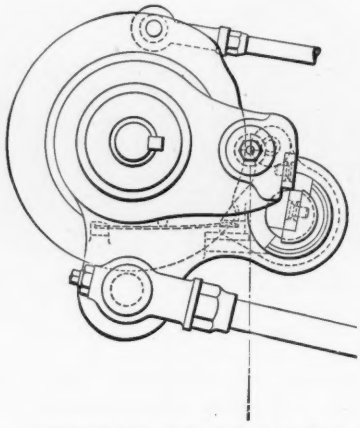


FIG. 2. WRISTPLATE AND STEAM VALVE GEAR

The cylinder is cast with metal, to stand 150 lb. pressure after 3 reborings. It is supported upon a sole plate which is extended to receive the dashpots and also to serve as an oil pan under the valve gear. Valves are double ported and liberal as to size, to give a full and quick opening for the passage of the steam.

The inverted type of dashpot is used in which the plunger is stationary and the dashpot is moved by the valve gear through the medium of the drop rod, and a ball and socket joint, permitting perfect freedom of the moving parts and uniform wear.

The crosshead has taper shoes, which fit snugly in

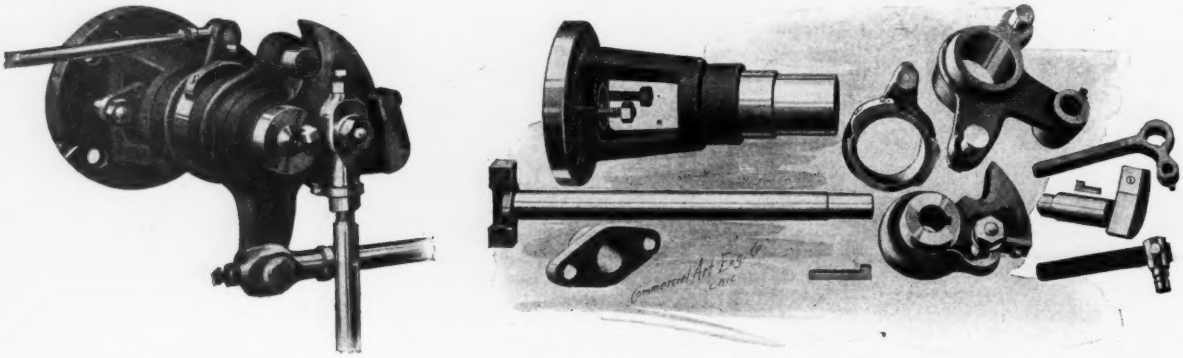


FIG. 2. VALVE MECHANISM OF VILTER ENGINE

The crosshead has side projecting flanges to hold in position the shoes, which have flanges on the ends, to prevent end thrust. Wear of the shoes is taken up by wedges, adjustable by screws and secured by set

a groove in the crosshead and after adjustment can be securely locked by 2 small bolts on the outside of the crosshead. The crosshead pin is turned slightly tapering at the ends which are ground in place, and the pin

secured by a nut and washer. The piston rod is a taper fit in the crosshead and is secured in place by a key.

In the releasing gear, which is of unique type, the trip-steel is engaged by means of a flat leaf spring, the tension of which can be varied within a great range.

The governor is of the variable weight, counterpoise type, so that the speed of the engine can be changed a few revolutions by adding weight to or taking from the counterpoise. For paralleling in electrical service, an additional shifting weight is provided to give close adjustment.

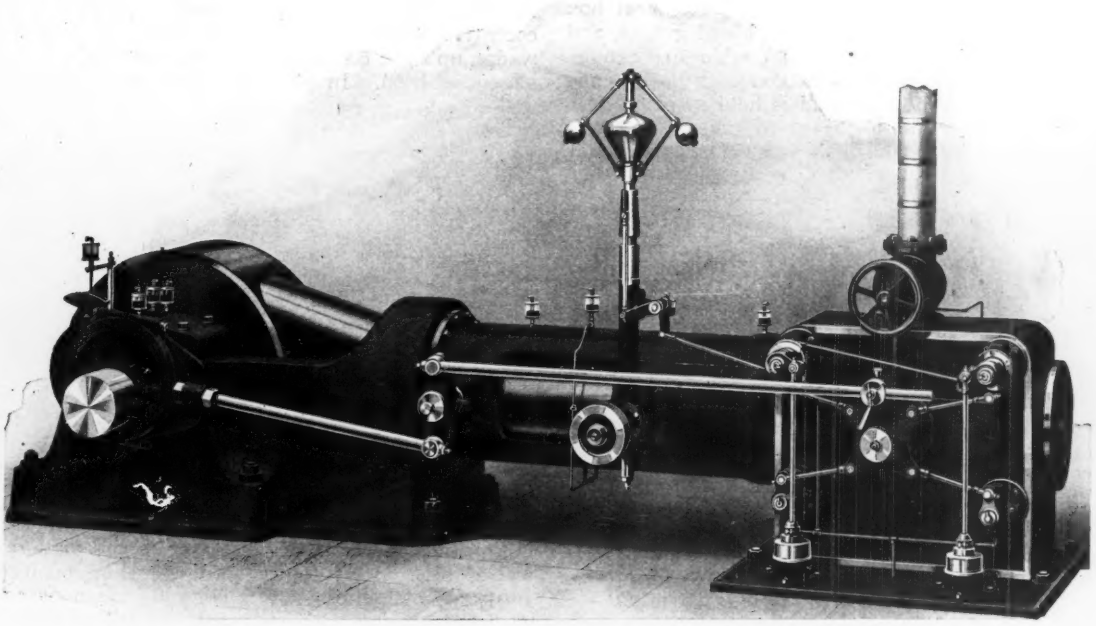


FIG. 1. REAR VIEW OF HEAVY DUTY WATTS-CAMPBELL ENGINE

The valve is tripped by means of a roller device which operates on a hardened knock-off cam controlled by the governor. By the great leverage and the roller, the strain on the governor is almost entirely eliminated.

Owing to the strong but light moving parts, and the quick and positive action of the vacuum dashpots, this valve gear is especially adapted to high speeds. The connecting rod is an open hearth solid steel forging slotted to receive the boxes, which at the crosshead pin are bronze, and at the crankpin bronze lined with genuine babbit. The adjusting wedges are the full width at the rod.

For engines operating at a high speed, oilguards entirely enclose the moving parts which have a continuous oiling system.

WISCONSIN HIGH SPEED CORLISS ENGINE

The Wisconsin Engine Co., Corliss, Wis.

THESE engines, of heavy duty or rolling mill type, have a maximum bearing upon the foundation, the frame and pillow block being in one piece with solid bottom crank pit to form an oil pan from which oil passes off through a drainpipe. Foundation bolts pass

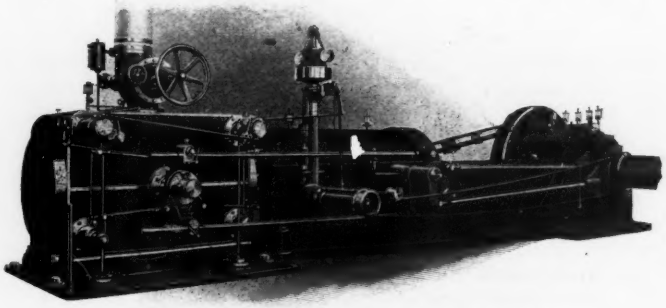


FIG. 1. DOUBLE ECCENTRIC WISCONSIN ENGINE

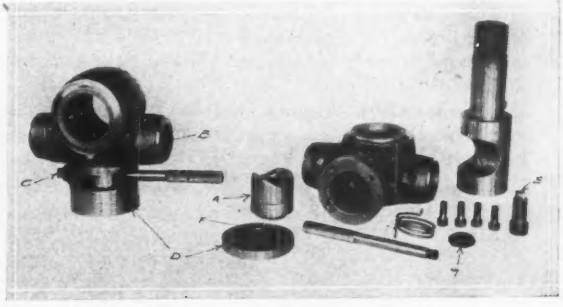


FIG. 4. WISCONSIN UNHOOKING DEVICE

The piston is built up with spider, bullring, and follower the weight being carried by the bullring which is very wide, and is flanked by 2 steam packing rings held out to place by light continuous springs.

Centering screws are provided for the bullring, so that when wear occurs the piston can be realined.

completely through the box shaped members.

The main bearing has 4 babbited shells, the bottom one seating flat on the frame so that it can be shimmed up, if necessary, the quarter boxes backed by full width wedges and the top shell separate from the cup.

The crank is a counterbalanced disk with forced fits

on shaft and crankpin. The connecting rod is a solid forging with steel or bronze babbit lined boxes for the crankpin and crosshead pin, adjusted by wedges moving parallel to the axes of the pins and controlled by screws from the side of the rod, so that constant centers are maintained. The boxes are thick at the parting to avoid pinching.

Wedge adjusted shoes are fitted to the steel box casting of the crosshead and to the bored guides, and the adjustment is controlled by double drive nuts. The pin is ground to fit the boxes, then flattened slightly at top and bottom, and is held in place by a ground taper fit in both cheeks of the crosshead, a heavy collar and studs. Push screws serve for easy removal.

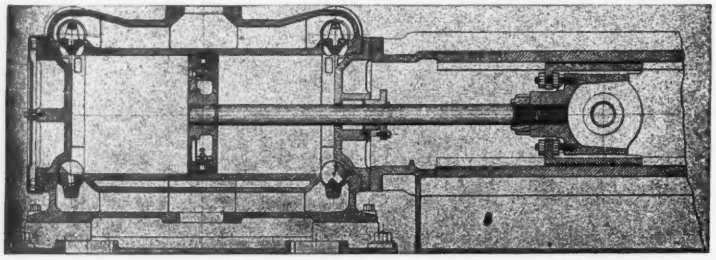


FIG. 2. SECTION OF CYLINDER, VALVES AND CROSSHEAD

Exhaust valves are set in the bore of the cylinder half their diameter to reduce clearance and are designed to prevent interference with the piston. Each exhaust valve is provided with a steel pin in the end working in a slot in the back bonnet, which prevents turning of the valve from any cause to a position where it could enter the piston space. The back bonnets are also doweled to the cylinder so that they must go on in correct position. Making all valves and steam ports double ported, with ports large and direct, reduces wiredrawing; the double ports being located equal distant from the vertical center line of the valve, so that the natural wear is taken up by gravity and steam pressure.

The valve gear is designed in such a manner that the drop lever is located between 2 bearings, giving the valve stem support on both sides, and bringing the push of the steam lever direct against the dashpot resistance. The drop lever is bored taper and around the valve stem is a taper sleeve whose edges closely fit a key in stem and lever. On the end of this sleeve is a nut which is tightened to wedge the sleeve between stem and lever and against the key thus locking all parts rigidly together.

The knockoff cam is at the end of the bonnet where it is operated by the governor on closely fitted bearings, and works a steel forged trip lever of such length that the leverage is 3 times the length of the end which engages the drop lever.

The trip lever is returned by a plain flat leaf spring whose tension can be changed at will, and an adjusting screw permits setting the trip steels so that the amount of engagement can be altered even while the engine is running. Safety cams are regularly supplied which are always ready, but do not interfere with operating conditions, so long as the speed is not excessive. Rope drive is recommended for the governor wherever possible.

With double eccentrics, cutoff takes place anywhere from zero to 82 per cent of the stroke. Ordinarily, the steam valve arms are connected by a rod, the forward one only being connected to the eccentric by the hook rod. Exhaust valves are operated by the usual wrist-plate actuated by its own eccentric.

The reach rod unhooking device is shown in Fig. 4.

In the assembled view, the handle is in operating position, and is pulled at right angles to disengage the hook block A from the hook rod which goes in hole B. On block A is a little groove which is turned eccentric with the axis of the block, and serves to wedge up tight on screw C holding the block in disengaged position. In plate D screw E inverted is inserted into hole F and locked by nut G, the hook block A working on the larger diameter thread on screw E. When block A is forced into operating position, it unscrews over the screw E jamming the hook rod, as well as engaging with the two taper fingers on driving block A. The small coil spring throws block A into operating position, after it has been loosened from binding screw C.

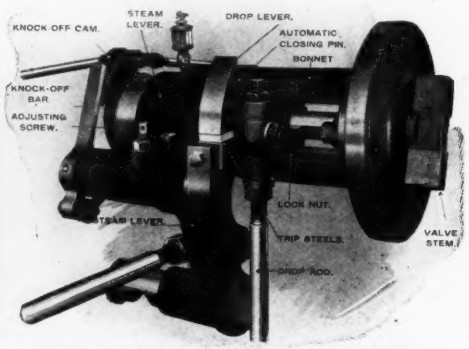


FIG. 3. WISCONSIN STEAM VALVE GEAR

Dashpots are of the submerged type, with the top flush with the foundation plate of the cylinder. They have double vacuum chambers, without cupleathers, and valves permit easy adjustment of either vacuum or cushion from the top while the engine is in operation.

This type of valve gear is particularly adapted to higher speeds, of 150 to even 176 r.p.m.

The piston is of the usual built up type provided with piston body junk ring. Follower and packing ring, the latter held out by flat leaf springs. The junk ring has bearing full width of piston and the piston body is arranged so it may easily be centered in the cylinder.

The piston body is of the usual built up type having junk ring, follower, and packing ring held out by flat leaf springs. The junk ring has screws for easily centering the piston in the cylinder and bears full width of the piston.

EXTENSIVE IMPROVEMENTS are being made in the light and ice plants of Victoria, Tex., which are owned by the Victoria Mfg. Co. The capacity of the ice plant will be increased 20 tons and that of the light plant more than doubled, and the factory buildings will be reconstructed of brick and steel. The company's cotton seed house will also be rebuilt, the new house to be a frame building and considerably larger than the present structure. A steam turbine and an electric generator of 500-kw. capacity, both of the most modern type, will be added to the equipment of the light plant, which will give the factory a capacity of 920 kw. and make it the most powerful electric light plant in this section of the state.

FOUR-VALVE ENGINE

Having the Advantages of Corliss Valves, Combined with High Speed Positive Action and the Automatic Shaft Governor

WITHIN THE PAST FEW years a new type of steam engine has been developed by several builders, which has a cylinder supplied with 4 bored valve ports, the same as for a Corliss cylinder. The greater number of these engines use a link gear with direct acting nonreleasing connections on the steam valves, while the exhaust valves are operated in the same manner as those on a Corliss engine of the releasing gear type. In this way, the exhaust valves operate at a constant travel by a fixed eccentric on the main shaft, and the steam valves have a variable travel depending upon the load and steam pressure. The eccentric which operates the steam valves is controlled by one of several types of shaft governors. The construction is designed to give the economy of a Corliss engine and at the same time permit of high rotative speed, to meet the demand for a high speed engine for direct connected service.

At first single ported valves were used, but as this necessitated excessive valve travel, double ported valves were developed and with the valve travel reduced the inertia of the moving parts was lessened which in turn permitted higher rotative speeds and steam pressures for a given sized unit with a material increase in power developed in proportion to the weight. Some very successful engines have even been constructed with triple ported valves.

In the 4-valve automatic engine, the main thought has been to secure a quick valve movement with as long a pause or dwell at each end of the travel as possible and in this way secure the same result by a quick positive closing as is secured in the Corliss engine by releasing the valve and closing it by means of a dashpot. Cards taken from some of the recent double-ported valve engines show that the travel of the valve at the moment of valve closure is practically as prompt as the valve closure with releasing gear.

BALL HIGH SPEED CORLISS ENGINE

The Ball Engine Co., Erie, Pa.

THESE engines are manufactured in the single cylinder and cross-compound type, both horizontal and vertical.

The distinguishing feature is the patented nondetaching valve gear, which permits the use of unbalanced Corliss valves of the form which, by the process of elimination, have become the standard for the best drop cut-off engines. These valves have no tendency to wear themselves or their seats out of true, and do not change the supporting area during the closed period.

The patented nondetaching gear of the Ball-Corliss engine holds the valves completely at rest for fully half a revolution at the time when the pressure on the valves is much unbalanced, and when movement would be detrimental. The gear is enclosed in a tight case containing oil, the height of which is shown by the oil gages.

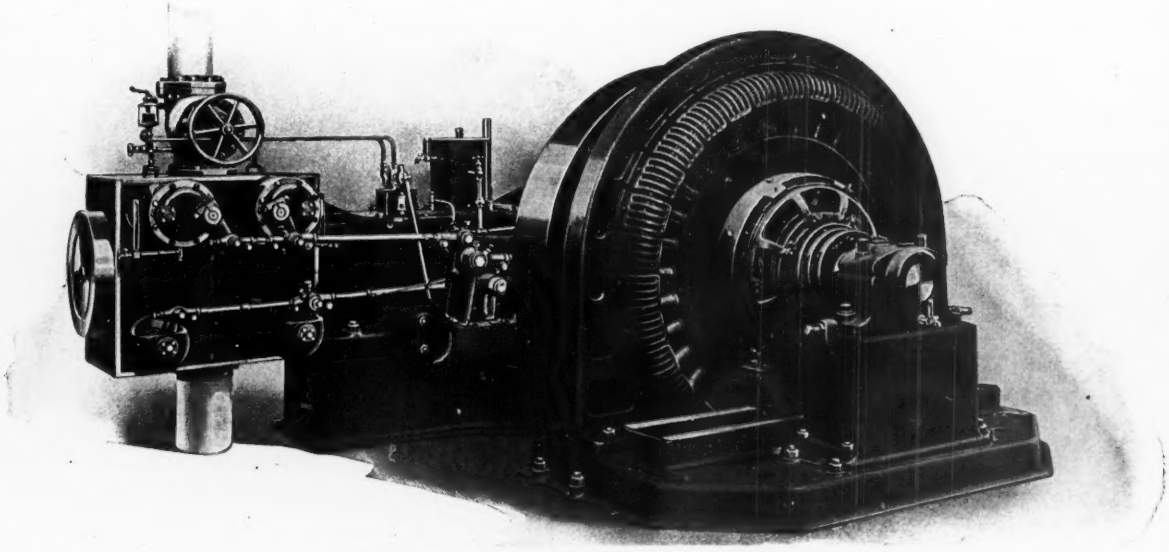


FIG. 1. BALL CROSS-COMPOUND CORLISS ENGINE

Shafts and pins of the gear are of hardened steel, ground true, and the bearings are hard phosphor bronze, all parts of the gear being interchangeable. Figure 2 is a motion diagram in which the movement of the eccentric rod is represented horizontally and the resultant movement of the valve vertically. At usual loads, the valves have their highest speed at the moment of opening and closing, the movement of the valve beginning at the middle of the valve gear travel, when all parts of the gear from the valve crank back to the eccentric are at their highest speed, consequently have the greatest leverage upon the valve at the only time that it moves at all hard. The design of the gear is such that all stresses are central with the members, so that there is no twisting to disturb the alinement of the members.

As the valves move only at the proper times and remain motionless at the times when they would move hard, and as flooded lubrication is used, perfectly smooth, quiet operation results.

This valve gear makes possible a high speed engine of Corliss type, with durable tight valves, the effect of which upon steam economy is apparent.

Cylinders of 23-in. bore and larger are built with

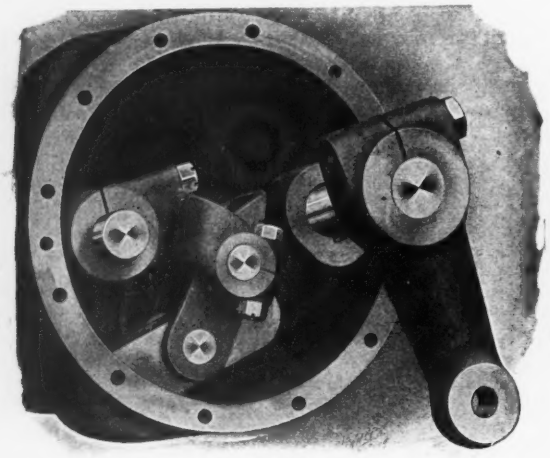


FIG. 3. BALL VALVE GEAR WITH COVER OF CASE REMOVED

the valves in the cylinder heads in order to keep down the clearance. In cylinders of 19-in. bore and larger the admission valves are triple-ported, and the exhaust valves are double-ported and driven by a wrist plate. In smaller cylinders the valve seats are formed integral with the cylinder, as in the usual type of long-stroke Corliss. As these cylinders are long in pro-

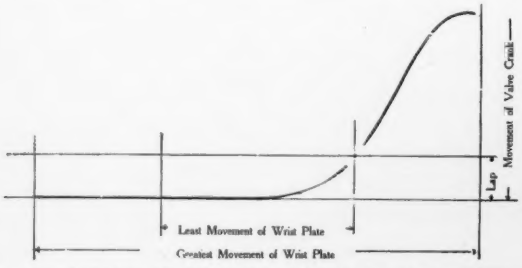


FIG. 2 DIAGRAM OF RELATIVE MOVEMENT OF WRISTPLATE AND VALVE

portion to their diameter, the clearance is sufficiently low to permit this construction. The admission valves of these smaller cylinders are double-ported and the exhaust valves single-ported. Exhanst valves are so designed as to close off the ports on both sides of the valve, and thus reduce the clearance space, and prevent lifting, if the steam expands below the exhaust pressure.

CHUSE NONRELEASING CORLISS ENGINE

Chuse Engine & Mfg. Co., Mattoon, Ill.

THIS engine has been designed to meet the demand for refinement in steam economy, simplicity, easy adjustments and high economy throughout the life of the engine. Frames, which are similar to the Chuse high-speed type, are massive, enclosed and self-oiling, with bored guides and quarter box main bearings. The connecting rod is a solid steel forging and has babbited steel shells for each bearing and wedge adjustment on both ends. The crankshaft is an open hearth forging with cast-steel disks and inserted forged-

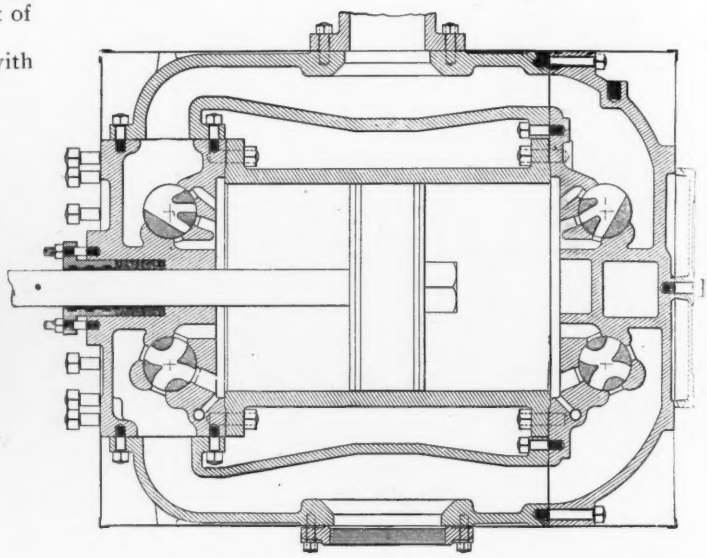


FIG. 4. SECTION OF BALL CORLISS CYLINDER AND VALVES

steel crank pins, and crossheads are cast steel with cast-iron shoes.

To obtain high economy, which necessitates correct steam distribution, ample steam openings and small clearance are provided and to maintain economy, valves are so designed that natural wear does not cause leaks. To give minimum clearance, cylinders have small bores and long strokes, and thus comparatively

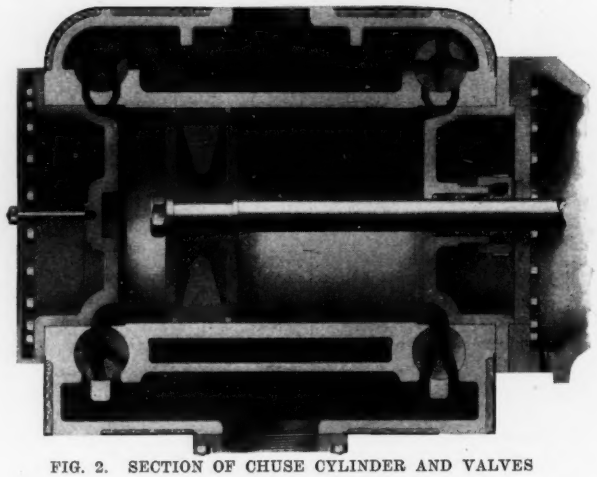


FIG. 2. SECTION OF CHUSE CYLINDER AND VALVES

smaller ports can be used; valves and ports are short, with valves set close into the cylinder walls. Also the reduced cylinder bore makes small space to fill with steam at the end of the stroke. It was also found that engines of these proportions, in spite of high piston speed, ran very quietly and compression could be cut down to the point of slow speed engines.

To obtain the best combination for prolonged economy due to tight valves, investigation showed that all valves having the ports and seats within the bottom

third of the circumference of the valve chamber were giving good results. Weight of the valves and the unbalanced pressure of the steam held the valve tight against the seat and the wear due to any natural cause ground the valve and seat together so that it remained tight indefinitely.

Valves and cylinders are also double ported to reduce the travel and wear, which also makes the regulation more sensitive, because the governor has to shift its position only slightly to make the range from zero to full cutoff.

Another feature which was found to affect seriously the tightness of the valves was warping due to unequal expansion, when the casting scale was removed on one side and left on the other. This was effectively overcome by making the valves as near tubular as possible, with the entire outside machined; so that these valves expand in an absolute straight line.

A plain wristplate motion as near the best releasing Corliss engine as possible was selected, because it was a tried design, was simple and accessible, so that it was easily kept up and adjusted, and it could be so ruggedly designed that it would stand almost any service. Careful design of proportions with proper travels and angles, give satisfactory quick opening, quick closing and a pause followed by a nearly imperceptible motion when under the greatest unbalanced pressure. Experiment proved to the designers that too long a pause gave the pressure on the valve time to settle the valve down into the oil, bringing surfaces of valve and seat in contact which required considerable force to get started into motion. A little less pause proved easier to lubricate and was considerably easier for the governor to handle.

Since the exhaust valves are unbalanced for half the entire stroke, and as it is just as desirable to get quick opening and closing and to have the same pause and slow movement on them during the unbalanced period, the same movement for exhaust valves was adopted.

and has wedge adjustments for wear. Reach rods are also adjustable by means of a right and left-hand screw, as in the releasing Corliss. Valve stems are also provided with a thrust bearing on the outer end of the bonnet, which can be lubricated on the outside and can be adjusted without taking down any part.

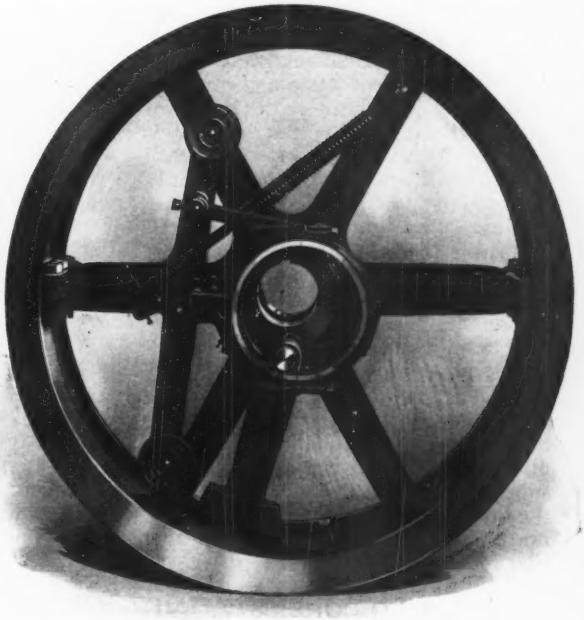


FIG. 3. THE CHUSE DESIGN OF INERTIA GOVERNOR

Rocker arms are omitted entirely by making the wristplates assume their duties. To do this the design must be rugged and with an exceedingly large bearing. The eccentric rod, which runs directly from the eccentric to the wrist plate, is made from a double extra strong pipe of large diameter swaged down at the ends to make solid connection, giving a form at once light and rigid and without vibration. By arranging the eccentric strap, eccentric rod brass head and the valve adjusting screw brasses in nearly the same place, and by putting the wrist plate bearing nearly central to this plane, nearly all side strain is eliminated, and

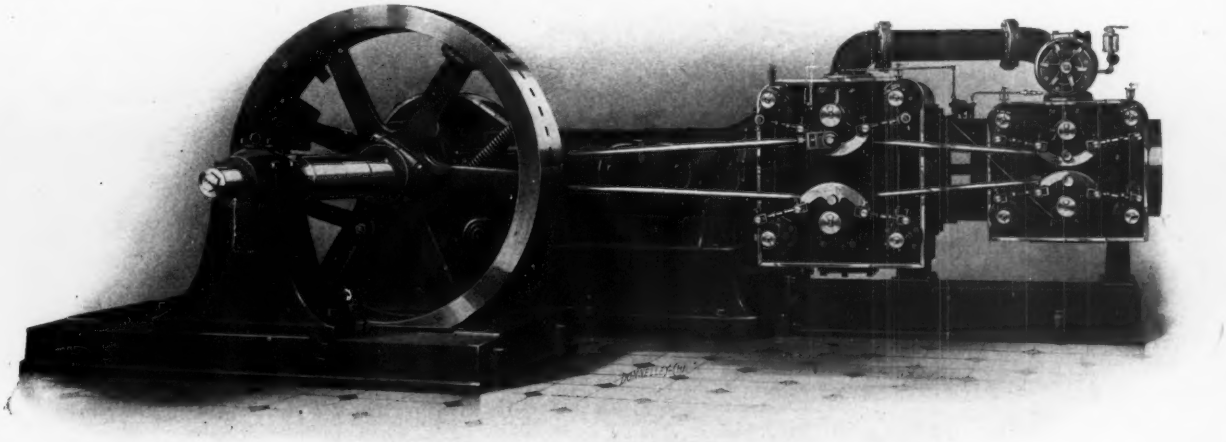


FIG. 1. THE CHUSE NONRELEASING CORLISS ENGINE

Valve stem stuffing boxes are open directly to the air and can be adjusted while in motion, and with this open construction, pins can be made large and the other parts heavy, as may be desired.

Bearings for the valve stems in the bonnets are bushed with bronze and renewal can be made in 15 min. A point of considerable advantage to the operating engineer is that every knuckle joint is of bronze

the only wear on the wrist plate bearing is that due to the weight on it.

As Corliss valves are unbalanced, it requires a powerful governor to handle them with ease; the Chuse governor is powerful, with weights so placed that they work in gravity balance at all positions and handles both high and low-pressure steam valves. A substantial centrifugal weight furnishes the power, and an inertia weight located near the rim makes quick action possible, this inertia weight also serving as counterbalance for the eccentric and strap. Any desired degree of regulation can be obtained with this governor and parallel operation can be had without resorting to any electrical device. All bearings are bronze bushed with bearing free to turn either inside or out, thus giving double safeguard against trouble due to cutting. Two simple adjustments control regulation or change speed. The coil spring acts in such a direction that most of the strain due to the centrifugal force of the weight is absorbed by the spring without coming on the bearing.

These nonreleasing Corliss engines are built in simple type from 75 to 800 hp., either belted or direct connected; in tandem-compound type of the same power range, and of cross-compound types from 150 to 1200 hp. The tandem compound type has an open dividing head between the cylinders and substantial supports for each cylinder. In cross-compound types the low-pressure valves are driven either by the governor or by a fixed eccentric as the conditions of operation require.

FLEMING CORLISS VALVE ENGINE

Harrisburg Foundry and Machine Works, Harrisburg, Pa.

WHETHER a standard or heavy-duty type of engine should be specified is entirely a question of the financial and operating conditions in each individual case. As between the single-valve type and the improved form of Fleming-Harrisburg Corliss, the annual maintenance and operating costs of the latter are such that the makers strongly recommend the adoption of the Fleming Corliss engine where economy is the controlling factor.

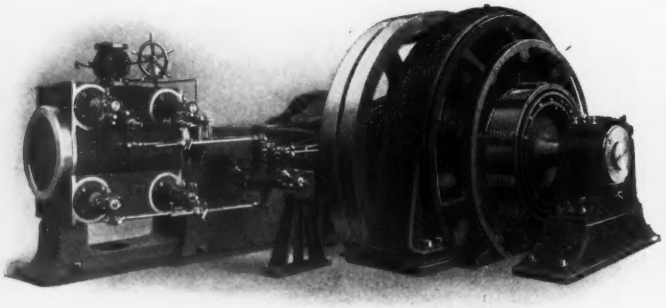


FIG. 1. FLEMING-HARRISBURG CORLISS VALVE GEAR

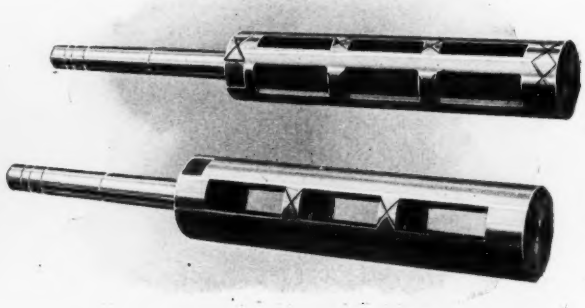


FIG. 2. FLEMING CORLISS VALVES

Frame, subbase, bearings, reciprocating parts and governor are similar to those described for the single valve engine.

In the Fleming-Harrisburg Corliss valve gear, 2 independent eccentrics are employed, one operating the steam admission valves, and controlled by the centrifugal-inertia governor, and the other, with fixed travel, driving the exhaust valves. In both cases, the motion of the eccentrics is conveyed through bell cranks to independent rocker arms. From the steam rocker arm a short adjustable rod operates a bell crank mounted on the projecting arm of the steam valve bracket. This is connected by an adjustable link to a second bell crank similarly mounted. To the short ends of these bell cranks are attached links which transmit the motion to the respective valve arms securely attached to the projecting valve stems.

Fast opening and closing is the advantage sought in all Corliss valve gear, and it is accomplished in this engine by the compounding of the angularity of the several levers, giving a valve motion free from complications. The exhaust valves are connected with an adjustable link, and their movement is accurately timed to obtain the best possible steam distribution.

Rocker arms are steel castings with carefully fitted bronze adjusting shoes, and bronze is also employed for the link and other boxes which are provided with lock-nutted slot adjustments. Connecting links are provided with right and left hand threads, insuring prompt and precise adjustment. The valve bracket with its attached stuffing box is designed to form a neat drain from which polished drip tubing leads away the water.

The Fleming-Harrisburg Corliss valves are the outcome of a lengthy series of experiments and tests, are of the multiported type and are slightly unbalanced, the resulting pressure being utilized to the best advantage to render them perfectly tight. Little power is required to drive them, and early and late points of cutoff are obtained without excessive angular movement over a range of from zero to approximately 65 per cent of the stroke.

The steam valves are housed in bushings, making possible prompt and inexpensive repairs, besides securing better metal for the seats and more accurate port alinement.

Exhaust valves are single-ported except in the largest engines. For both the steam and exhaust valves, a special grade of material is employed as the result of long research and experiment.

HIGH SPEED CORLISS ENGINE

Hooven, Owens, Rentschler Co., Hamilton, Ohio.

THIS is strictly a Corliss valve engine, with all the good points of that design. The stroke however is shortened, the dashpots and releasing mechanism eliminated and the flyball governor replaced by an inertia type shaft governor.

The builders' experience has convinced them that the limit of speed for Corliss or semirotary valves, with the necessary margin for successful operation, should not be over 200 r.p.m., and they build this type of engine in sizes from 50 hp. up, with speeds from 125 to 200 r.p.m. inclusive, in single cylinder, tandem and cross compound types, of both horzontal and vertical design.

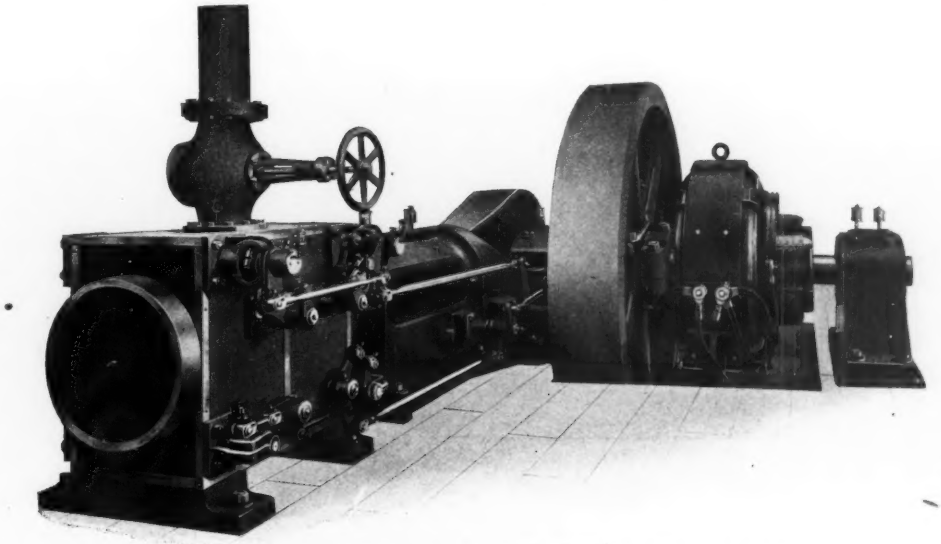


FIG. 1. DIRECT CONNECTED HAMILTON, POSITIVE DRIVE CORLISS ENGINE

The valve gear is designed to give the quickest possible opening and closing to the steam valves, while they are balanced, and a pause or rest during the unbalanced period. The central rocker is eliminated and a series of bell crank levers is used which gives double distorted motion to the valves. All parts of the gear are made light yet amply strong and are thus better adapted for high speed and quick reversal.

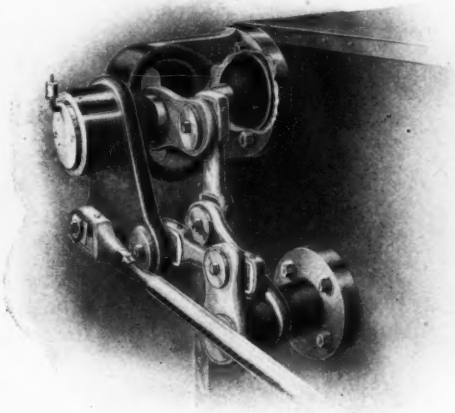


FIG. 2. DETAIL OF STEAM VALVE GEAR, SHOWING STEAM PACKING

Valve stems have a long bearing in the brackets, both inside and outside of valve cranks, the entire vavle gear being as close to the cylinder walls as good design permits. The stems are equipped with special patented metallic packing of spherical design, which readily adapts itself to the wear of the stems or brackets. Valve gear rods are of steel with right and left hand threads, stub ends and links of bronze and fitted with adjustable bronze boxes with wedge and locking bolts to take up wear.

Both steam and exhaust valves are double ported, placed in the cylinder body and are supported full length at all times.

In the view of the inertia governor, Fig. 3, the eccentric, supporting sleeve and balancing ring are shown in full lines and the weights and springs on the opposite side of the wheel are shown in phantom lines.

The governor is in perfect static and rotative balance; the only motion that the arms and links have during the revolution is that due to change of impulse

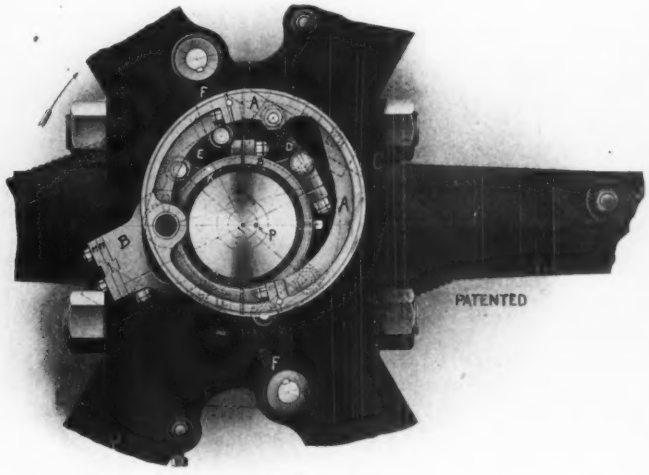


FIG. 3. INERTIA SHAFT GOVERNOR OF HAMILTON 4-VALVE ENGINE

of the crank pin and does not originate in the governor itself. If the springs are not attached and the wheel is slowly turned through one revolution there is no tendency at any part of the revolution for the weights to change their position.

The eccentic is carried on a large fulcrum pin which is supported on each side of the eccentric in a support ring K securely fastened to the shaft. This feature makes the eccentric independent of the wheel to a great extent, permitting of a change in the angular advance without disturbing the wheel.

Carried on this supporting ring, free to rotate and next to the eccentric, is the balancing ring B, connected to the arms F by links E and to the eccentric A by link D. Arms F are connected through shafts with the governor weights on the back side of the wheel and any movement of these weights will cause the balancing ring B to rotate about supporting sleeve K and cause the eccentric to swing across the shaft, changing the angle of advance and the throw of the eccentric. Weights H are added to balance the weight of the eccentric, strap and rod, concentrated through the link D at the boss at the opposite side of the ring.

All pins are supported in double bearings so that the force is central with the piece moved. Supporting sleeve, balancing ring and eccentric are all in halves and can be removed from the shaft with little trouble.

The springs are provided with knife edges at each end, and so placed that the direction of force is nearly opposite the centrifugal force in the weight, relieving the weight shaft of pull.

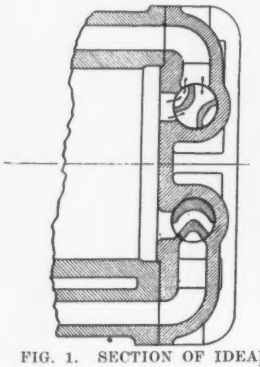


FIG. 1. SECTION OF IDEAL CORLISS CYLINDER HEAD AND VALVE

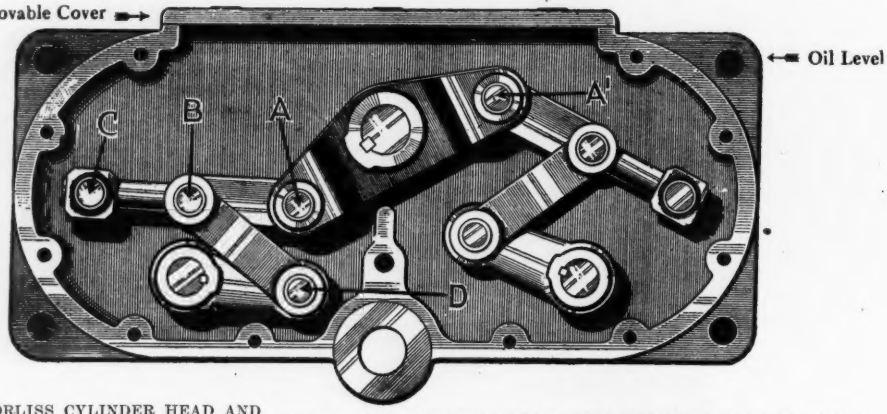


FIG. 2. ACCELERATING GEAR WITH FRONT OF CASE REMOVED

The valves are symmetrical, with suitable bridges properly distributed for stiffness, are multi-ported, and unbalanced when closed, so that the steam pressure holds them to their seats. Their disposition in the cylinder heads instead of in the cylinder body, is made to get the valves in closer to the piston and to shorten up the distance the steam has to travel to reach the piston. This cuts down the waste space and the amount of dead surface exposed to the steam during expansion, and gives a high steam economy.

The Ideal accelerating valve gear has pins hardened and ground, and the links bushed, so that with the valve gear completely submerged in oil, smooth, quiet operation and long life are assured. The gear, which controls the admission valves, transmits the motion that causes the valves to come to full closed position and remain there at rest for about one-half the revolution of the engine until time to reopen; and to open and close in a rapidly accelerating movement, similar to the "pick-up" and "drop" of the Corliss detaching gears.

This is an important feature because there can be no wear while the valves are at rest and they can wear no shoulders in the seats, because they travel to the same closed position every time, no matter what the load is. This is the true Corliss action produced by means of the patented gear, simple and positive in its action without releasing or detaching the parts. This gear is all contained in a compact, oil-tight gear box, located on the rigid engine frame with the mechanism completely submerged in oil.

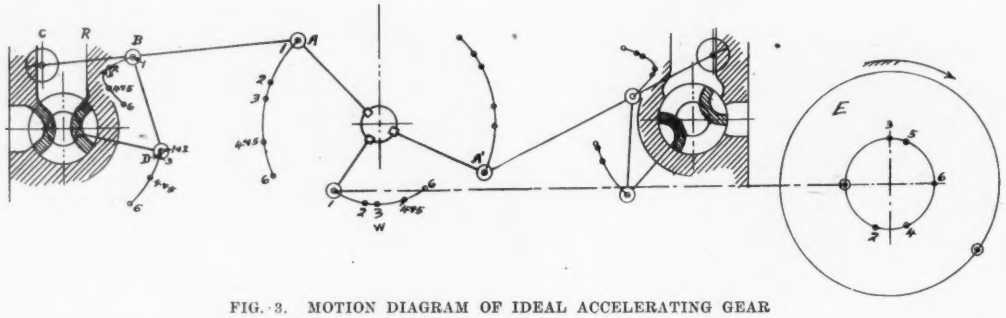


FIG. 3. MOTION DIAGRAM OF IDEAL ACCELERATING GEAR

IDEAL CORLISS VALVE ENGINE

A. L. Ide & Sons, Springfield, Ill.

IN all details except the valves, cylinders and valve gears, this engine follows the lines of the Ideal single-valve engine.

The valve is of simple form, with only enough port edges to give the necessary port opening with the

The motion diagram shows the elements of the gear and the manner in which the motion is developed and imparted to the valve; but does not attempt to show the actual location of gear and valves. The motion may be easily studied by tracing step by step the successive positions of the several parts for one end only. For this purpose, we will trace the movement of the valve marked, "Head End."

The eccentric E travels around its circle and drives the eccentric rod, which connects to the wrist-plate pin W seen in the picture of the engine as a hanging crank on the outside of the gear case. Inside the gear case is a rocking plate with 2 arms, A and A^1, for driving the head end and crank end valve linkages. To the arm A is pivoted a lever on which is formed a cylindrical tail rod, which slips through a trunnioned guide C, which serves as the fulcrum. At a suitable point B on the lever is pivoted a link which connects to the valve crank D. For the sake of clearness, the diagram omits the connecting rods which reach from gear box to cylinder, as these rods and their connecting arms merely transmit the movements without affecting the velocity ratios.

The corresponding positions of the various points are numbered alike. Starting at the position, 1, as the eccentric moves up to position 3, the arm A moves from its position 1 to position 3, and the point B on the lever is forced to the left to its position 3, shoving the tailrod R through the trunnioned guide C. During this movement, the link connecting the points B and D swings about D as a center so that the valve crank is not moving during this period.

As the eccentric moves from 3 to 5, point W travels from 3 to 5 on its arc, and point A travels downward from 3 to 5, point B being drawn downward to the right, and tail rod R sliding to the right through the trunnioned guide C, as the point B advances from point 3 on its curve to point 5 on its curve. This draws the valve crank downward from its position 3 to position 5, and the valve is rotated by the amount of its lap, bringing it to the point of admission. As the eccentric travels from 5 to 6, the points W, A, B, and D make the corresponding travel, and the valve opens for the admission of steam.

As the eccentric travels from 6 to 4, point W travels back from 6 to 4 on its arc, and points A, B, and D make corresponding movements, bringing the valve back to the point of cutoff; and when the eccentric reaches the position 4, the valve is brought to its full closed position. While the eccentric moves from position 2 to position 3, or approximately half a revolution of the engine, the valve remains at rest.

NAGLE 4-VALVE ENGINE

Nagle Corliss Engine Works, Erie, Pa.

ECONOMY in the use of steam is accomplished by having a valve mechanism that gives quick admission, sharp cutoff and free exhaust; strength is obtained by liberal use of the best material; close regulation is secured by an automatic shaft governor which is simple, yet fully controls the speed of engine under various loads and steam pressures.

The frame is of standard tangye type, with heavy main bearings carrying quarter boxes with large wearing surfaces, fitted with wedges for adjustment by lifting screws through the pillow block cap. A large opening in center of the cap allows the hand to be inserted to feel the temperature of the shaft.

Double-ported valves, 2 for steam and 2 for exhaust, are placed near the bore of the cylinder so that the clearance is reduced to a minimum; the valve seats in the cylinder are bored out and the faces of valves and seats carefully scraped to fit each other. The exhaust valves are located under the cylinder, thereby securing perfect drainage, and the exhaust chamber at bottom is operated from the cylinder by sufficient air space to prevent any possible cooling from exhaust steam striking the cylinder wall. The steam valves are made to relieve themselves in case of water in cylinder, thereby preventing the breaking of cylinder heads.

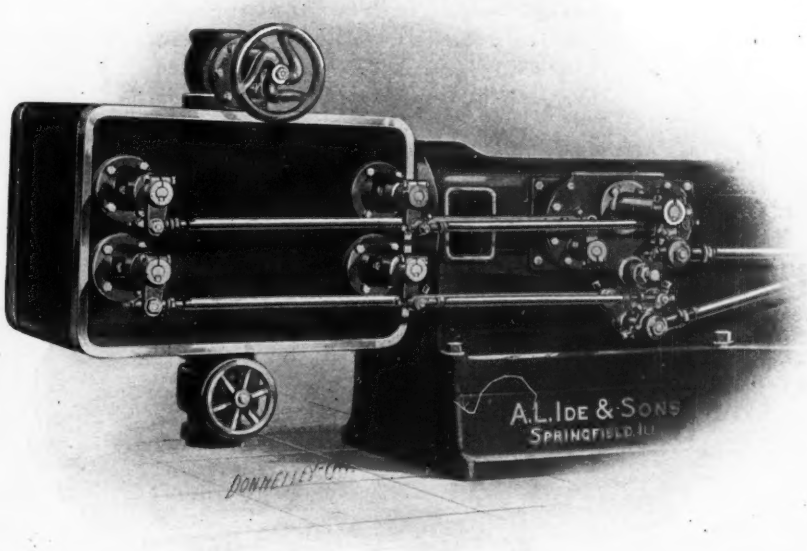


FIG. 4. IDEAL CORLISS VALVES, RODS AND ACCELERATING GEAR CASE

The valve gearing consists of an arm swung to the valve bonnet bracket, a bell crank pivoted on a stud extending from the side of the cylinder and links

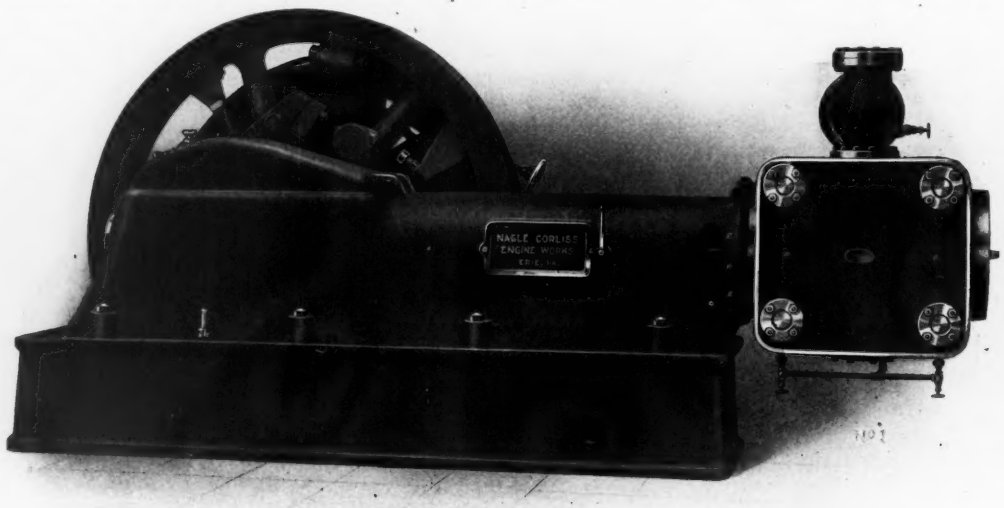


FIG. 1. ENCLOSED TYPE NAGLE 4-VALVE ENGINE

to connect those levers and to the valve crank. It is designed for very quick admission of steam and sharp cutoff and is regulated by the automatic shaft governor; all parts are accessible and are provided with means for adjustment. Steam and exhaust valves are driven from separate eccentrics and therefore can be properly set to suit the varied conditions.

Three moving parts make up the governor; the inertia bar, the link, and the spring. Upon a steel pin

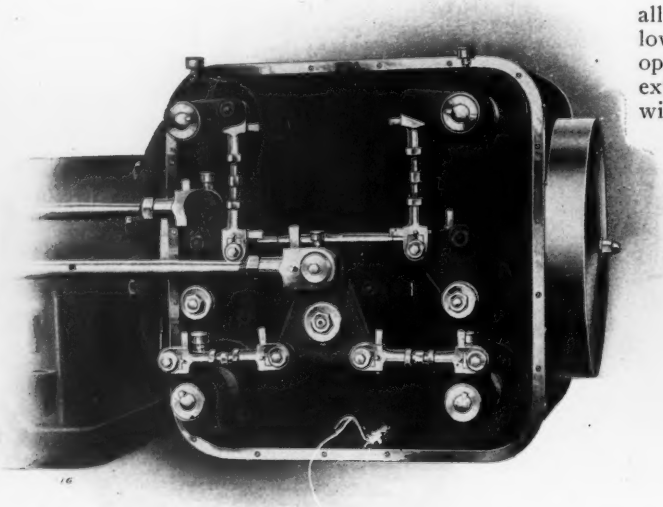


FIG. 3. STEAM VALVE GEAR ACTION

which is secured to one of the governor wheel arms swings the inertia bar, which is carefully bored and has a hardened steel bushing inserted. Between this bushing and the hardened steel pin are a series of hardened steel rollers, making the bearing practically frictionless. The link provides the connection between the inertia bar and the leaf spring, giving a governor which is perfectly balanced. Speed is adjusted by changing weights, and sensitiveness by changing the spring tension by means of the adjusting bolt at the end of the spring holder arm.

RIDGWAY 4-VALVE ENGINE

Ridgway Dynamo & Engine Co., Ridgway, Pa.

EXCEPT for the valves, valve gear and cylinder, the details of this engine are the same as for the Ridgway side crank engines with single valve.

Valves are placed in the barrel of the cylinder in all sizes, ports are short and direct, and clearance is as low as quiet operation will allow. The steam valves operate in replaceable cages or bushings made from extra hard iron, ground on the outside and put in place with a heavy force fit. After the cages are in place

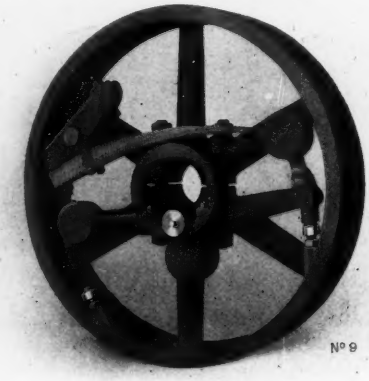


FIG. 2. NAGLE INERTIA GOVERNOR

they are ground true on the inside and the valves are ground to fit. The steam valves are double ported with a small movement of the valve yet leakage can take place past but 2 edges. The valve spans a short arc and any wear which occurs makes the valve tight-

er, since gravity and steam pressure force the valve to its seat. The valve is symmetrical and can be turned to present a new wearing surface as often as desired.

During the moving period the average unbalanced pressure on the exhaust valve is not as great as on the steam valve, hence the wear is small and for this

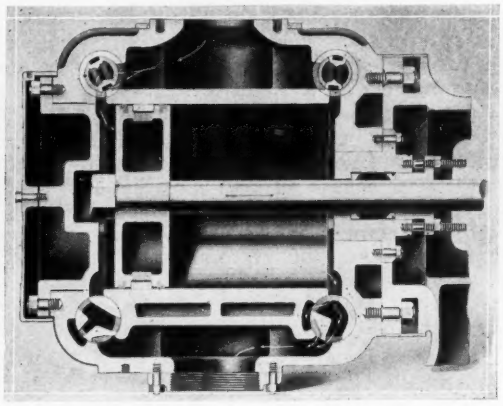


FIG. 1. SECTION OF RIDGWAY CYLINDER AND VALVES

reason cages are not used with the exhaust valves, but these valves are double ported and have only 2 edges past which leakage can occur.

Valve stem brackets are open on one side and the stuffing boxes are easily reached. The valve stem is supported at the outer end by an adjustable bronze-lined bearing. The valve stem stuffing boxes are filled with a special metallic packing.

Fig. 2, there is mounted on the bed a cast-iron case, called the "gear case," combined with the rocker bracket which supports the exhaust wrist plate. Three shafts pass entirely through the gear case and are supported by bronze-lined bearings in each side of the case. The lower shaft is on the vertical center line between the 2 upper shafts and has mounted thereon

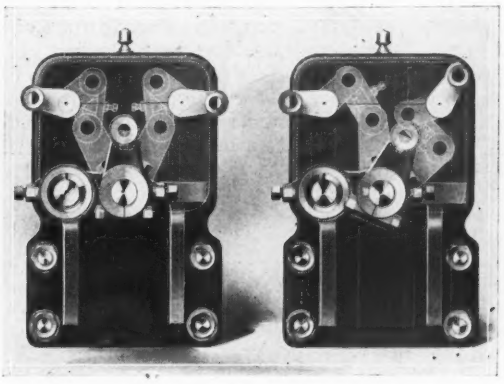


FIG. 3. PHANTOM VIEW OF GEAR CASE

3 arms, 2 inside of the case and one outside. The outside arm is connected through the eccentric rod directly to the eccentric. The inside arms are the 2 sides of a single V-shaped casting, each side of which is composed of 2 parallel arms. Through the outer ends of these arms passes a large pin, which forms a bearing between them. Both of the upper shafts have 1 arm outside and 2 arms inside of the case. The

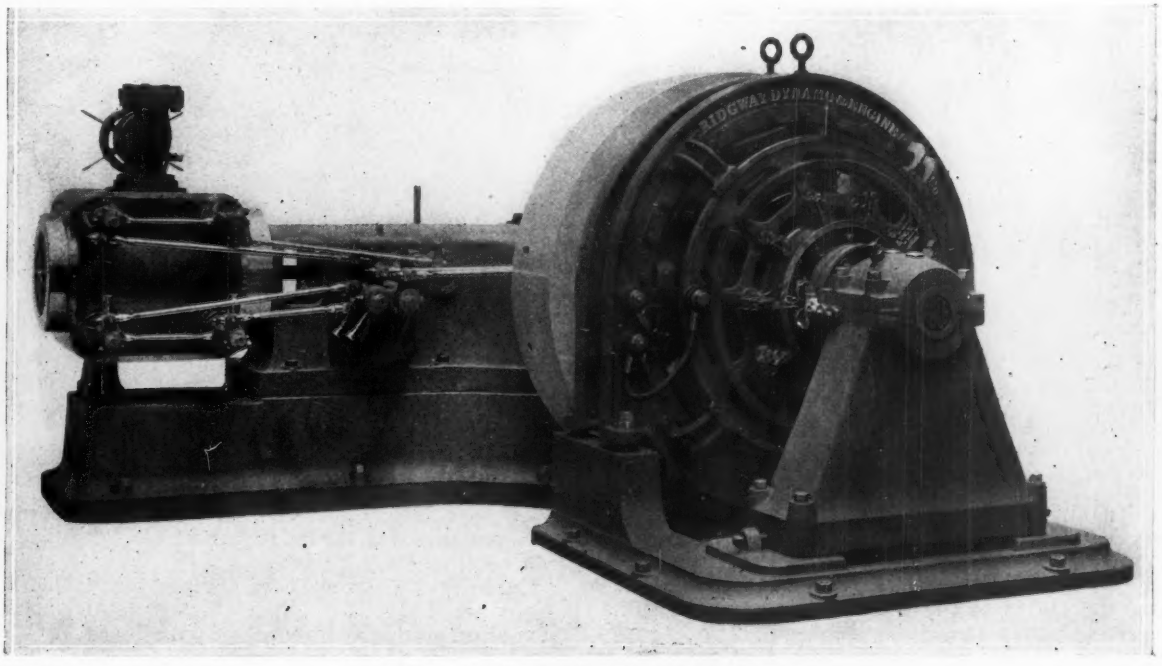


FIG. 2. ARRANGEMENT OF VALVE GEAR

The first feature which will be noted is the valve gear, and in the mechanism which controls the steam valves will be found the principal difference between the older and newer types of engine. Referring to

latter are parallel, with a bearing between their outer ends, corresponding to and alining with the bearings between the arms on the lower shaft. The 2 sets of arms are connected by links. From the outside arms

on the upper shafts, reach-rods extend to the arms on the valve stems.

By mounting the gear case on the bed, the valve stem brackets are relieved of all strains, except those necessary to open and close the valves; and the brackets can be made larger and more accessible, making it an extremely easy matter to repack the valve stems.

The accelerating gear is a system of toggle-joints, by means of which the motion from the eccentric is so modified that the valves are at rest during most of the unbalanced period, and opening and closing occurs when they have maximum velocity. The travel of the valves after closing is only enough to secure a satisfactory seal, so that friction in, and strains on accelerating gear are reduced to a minimum and it operates easily and noiselessly, even when comparatively loose. The port openings are liberal at points of cutoff up to and including ¼, without being greater at later points than is necessary or desirable.

The exhaust valve gear is identical with that used on releasing gear Corliss engines, but the wristplate motion instead of being mounted on the cylinder, is located on the same bracket which carries the steam valve gear. The wristplate motion cuts off excessive overtravel and by reducing the total movement of the valves, allows them to rest during the period when the unbalanced pressures are greatest, decreasing wear and friction, with consequent longer life of the valves and gear.

THE UNIFLOW STEAM ENGINE

ESSENTIALLY, this engine consists of a cylinder with exhaust ports at the center which are uncovered by the piston at about 0.9 its outward stroke, so that valves are used only to admit steam and any type now common for that purpose will accomplish the results, although among German manufacturers the poppet valve is prevalent.

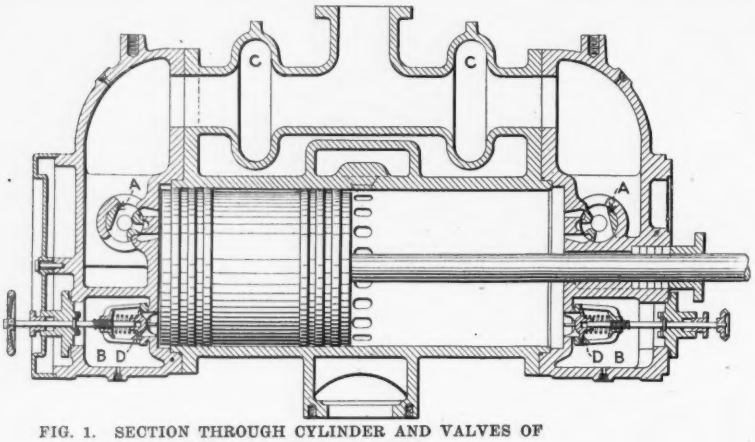


FIG. 1. SECTION THROUGH CYLINDER AND VALVES OF NORDBERG UNIFLOW ENGINE

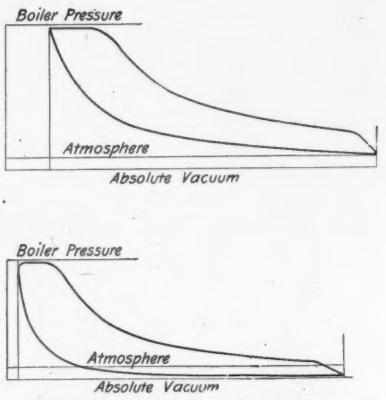


FIG. 2. NONCONDENSING AND CONDENSING DIAGRAMS FROM UNIFLOW ENGINE

Initial cylinder condensation, due to heat exchange between the steam and the cylinder walls, has always been the source of the greatest thermal loss within the cylinders of reciprocating engines. This loss grows per unit of area with longer time of contact, with greater temperature difference between the steam and the walls and with the force of throw and whirl of the steam against the walls.

At the steam end of the uniflow cylinder the temperature range is not great as there is no flow of exhaust steam across the surfaces and compression raises the temperature to that of live steam; while at the exhaust end of the stroke, that is, beyond the middle of the cylinder, the temperature remains nearly at that of exhaust. When the exhaust contains no moisture compression superheats the steam remaining in the cylinder. Compression is then practically adiabatic, so that the temperature is high even though the pressure does not exceed boiler pressure; hence, the face of the piston and the cylinder head are heated to at least full temperature of the incoming live steam. While superheated steam may be used to advantage in the uniflow engine it is not so essential as with the ordinary type of reciprocating engine as cylinder condensation is largely done away with.

Prof. Stumpf, originator of the uniflow engine, makes the statement in a recent book that "The extraction of energy from steam by compounding and superheating are seemingly false lines of development consequent upon the use of the counterflow system. Let the counterflow system be replaced by the uniflow and you thereby obtain a cylinder with the utmost possible constancy in its thermal conditions; in other words, a really adiabatic cylinder. Change from the counterflow to the uniflow system results in thermal simplicity and enables economic efficiency to be obtained without the necessity of multistage expansion or superheating."

Since compounding appears to be unnecessary, a good vacuum can be used to advantage with a single cylinder. As an example of results reported by Prof. Stumpf in regard to economy of this engine:

An Ehrhardt & Sehmer engine, 24½ by 39 in., with a steam pressure of 140 lb. at a temperature of 376 deg. F. or 15.1 deg. superheat, developed an indicated horsepower on 12.25 lb. steam per hour. With an unjacketed uniflow engine built by John Musgrave & Sons, Bolton, England, a steam consumption of 9.9 lb. per hr. per indicated hp. was secured when initial steam pressure was 162 lb., superheat 146.4 deg. and a good vacuum.

Unidirectional steam flow engines can easily be adapted to all special conditions of working, including locomotive, marine and portable engines.

NORDBERG UNIFLOW ENGINE

Nordberg Mfg. Co., Milwaukee, Wis.

THE Nordberg uniflow cylinder contains no exhaust valves, but in the middle of the cylinder a ring of ports is cut which is uncovered by the piston at the

end of the stroke, so that, in effect, the piston is the exhaust valve. The 2 steam valves A, Fig. 1, are located in the cylinder heads and the steam spaces over the valves become a steam jacket for the heads. The clearance pocket B is also kept filled with steam so that the head is completely steam jacketed. Thus the face of the piston and cylinder head of the uniflow engine are exposed to exhaust temperature for only the very short time that it takes the piston to uncover the exhaust ports.

On the return stroke the steam at exhaust temperature and pressure is caught between the piston and cylinder head, and, as the piston moves back, this steam is compressed, so that at the end of the stroke, pressure in the clearance space is equal to the steam line pressure. The temperature also increases not only due to the heat of compression but also to the absorption of heat from the head jacket, so that when the steam valve opens, the incoming steam meets no cold surfaces and condensation is largely prevented.

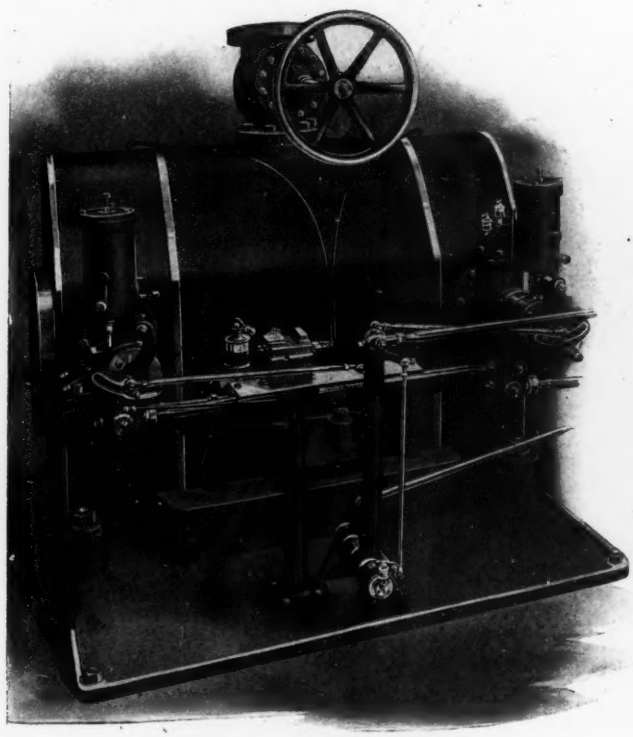


FIG. 3. VALVE GEAR SIDE OF UNIFLOW CYLINDER

Around the cylinder is a cast belt serving as the exhaust passage in the middle, and the steam chest is cast with the cyliuder and is provided with 2 drums, C, to take up expansion without distorting the cylinder. It should be noted that the cylinder contains no flat surfaces.

Valves are of Nordberg 4-ported type giving large area of opening with small movement of the valve, so that the actual valve travel is no more in valves of this type than in a single ported Corliss engine running at half the speed.

The valve gear, which is specially designed for high speed and hard service, is supported on a large bearing formed by extension of the steam bonnet. This steam arm is provided with 2 bearings for the hook, one on each side of a central plane, so that the entire valve gear is symmetrical with respect to this central place and there are no overhung parts or side strains. The trip steels are exceptionally wide and the dashpots, mounted above the bonnet, are of the spring type to insure positive action at high speed.

In the releasing mechanism, the hook carries an extended arm terminating in a roller which rides in a cam consisting of 2 circular arcs whose center is the point of suspension of the cam on the valve arm. This cam is driven by a separate drive rod and the hook is released when the roller passes from the outer to the inner circle of the cam. In general, the mechanism is the same as used on Nordberg Patent Full Stroke valve gear.

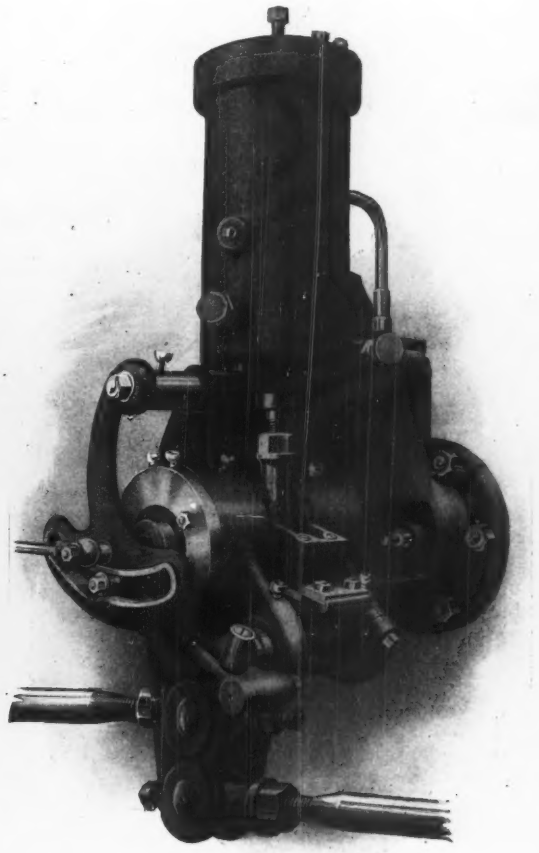


FIG. 4. STEAM VALVE GEAR AND TRIP MECHANISM

As seen in Fig. 1, a large relief valve D, opening into a pocket B in the cylinder head, serves 2 purposes.

1. It gives large area to relieve the engine from any entrained water, although this engine will handle much larger quantities of entrained water than a 4-valve engine owing to its large exhaust port area.

2. If, when running condensing, the vacuum should be lost, it is necessary to provide the engine with a larger clearance in order to prevent excessive compression. These valves therefore open automatically, and if it is then desired to continue to run non-condensing means are provided to back these valves off their seats, thus increasing the clearance by the volume of the clearance pocket.

The most pronounced features of the Nordberg Uniflow engine are its large capacity for overload and

its flat steam consumption curve. The engine will take an overload of 100 per cent with an increase in steam consumption of about 10 per cent.

The engine is particularly adapted to rolling mill service, street railroad and lighting work and general power purposes where the load is subject to wide fluctuations, or, in other words, where the load factor is low.

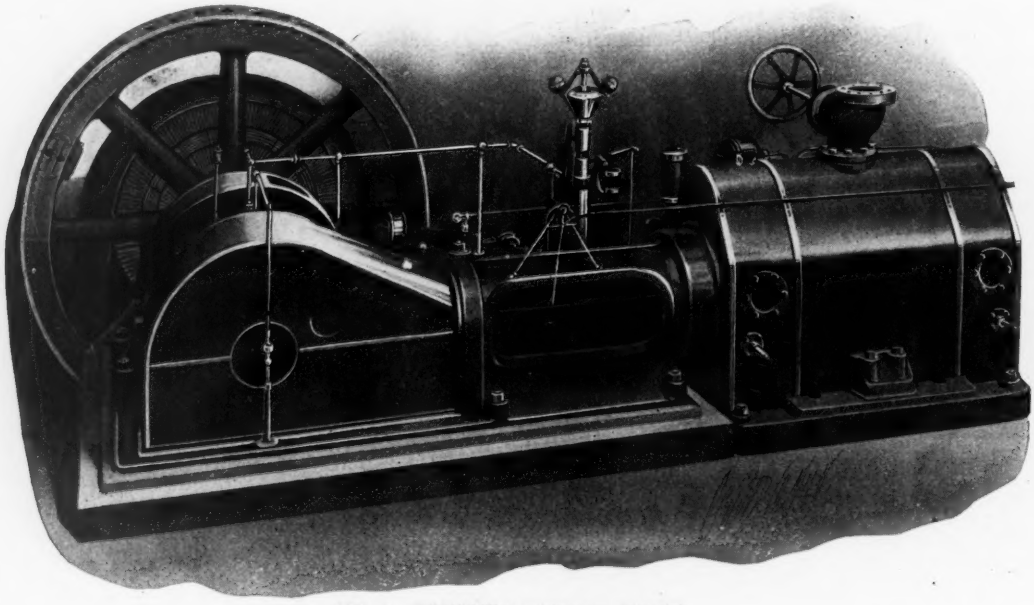


FIG. 5. NORDBERG UNIFLOW ENGINE

Corliss valves have been adopted to conform to usual American practice, although the Nordberg Co. builds engines with poppet valves to use the highest pressures and superheats as in German practice, when so desired.

THE LENTZ ENGINE

Erie City Iron Works, Erie, Pa.

PROBABLY the most interesting features about the Lentz engine are that no elastic packing is used throughout the engine, that the valves maintain their tightness indefinitely, the special type of mechanism for operating the valves and a simply constructed governor.

In the sectional view, Fig. 2, is shown the framing of the girder type with substantial feet to take the foundation bolts. The low-pressure cylinder is bolted to the frame and the high-pressure cylinder is secured to it by a distance piece. The feet of this cylinder are free to slide on foot plates with changes of temperature. The piston body is turned slightly eccentric so as to get a large bearing surface on the bottom of the cylinder.

Stuffing boxes, which are shown in section in Fig. 3, are bored and ground to within 0.001 in. of the exact dimension and in them are placed a series of cast-iron rings, turned and ground to fit the stuffing box and accurately faced. These rings do not fit the piston rod. Interposed between them are the 5 cast-iron rings having a square cross section which fit the piston rod to the same fraction of an inch. These are known as the floating rings. Oil can be kept circulating in the stuffing box, if necessary, but water, the result of cylinder condensation, is sufficient to keep the box tight right under pressure as great as 200 lb.

An enlarged sectional elevation of the admission valve is given in Fig. 4. This is a double-seated poppet valve, with seats not more than ⅛ in. wide. The valve spindles which are ground to fit the long bushings shown have no stuffing boxes, but bushings are bored and ground to fit the valve spindles within 0.001 in., grooves are turned in the spindles and there is no trace of leakage. The valves are turned to such diameters that the lower one will just pass through the upper opening. No dash-pots are used, the valve being moved by a cam acting on a roller. When the valve is seated the cam is not in contact with the roller, but the amount of clearance is too small to be shown in the drawing. The roller is always in contact with the cam until the valve is seated and, consequently, the engine makes no noise when running at speeds as high as 200 r.p.m.

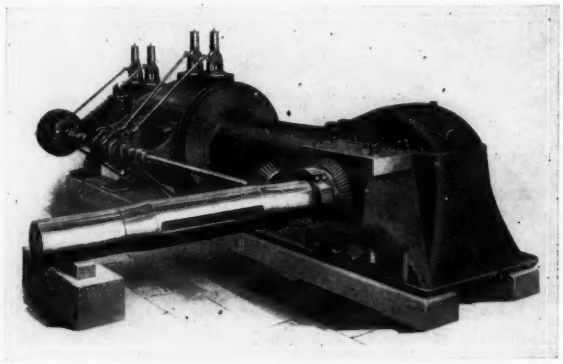


FIG. 1. LENTZ ENGINE WITH FLYWHEEL REMOVED

Alongside the engine runs a horizontal lay shaft, shown in Fig. 1, which is caused to rotate by a bevel gear between it and the crank shaft. This gear is very peculiar. In order to secure smooth running the gears constituting the drive are in the nature

of friction cones and the shaft is driven by pressing the cones together. To prevent slip, however, teeth are provided, but these are very shallow, the points being turned off. The gears are inclosed in an iron case and run without noise. On the shaft are grouped eccentrics, one for each of the valves. The rods of these eccentrics are coupled directly to the ends of the cam levers as shown in Fig. 1. Steam eccentrics can have their throw reduced to nothing by sliding the eccentrics on a block keyed to the side shaft and these eccentrics are moved by a governor regulating the point of cutoff.

The governor is of a novel type; there is a heavy external inertia ring, and 2 centrifugal weights, which are controlled by a flat spring that can be easily removed or replaced in a few minutes. The action of the governor shifts the eccentric longitudinally, and so alters its throw. The 2 weights are pivoted on a carrier, keyed to the side shaft, these weights and the carrier being attached by a spring and a knee joint to the outer ring, which performs the functions of a flywheel. When the least change of load, and, consequently, of speed, takes place, the inertia of the outer ring which tends to keep its speed constant, causes it to move with relation to the carrier, and moving the eccentrics alters the cutoff to suit the changes of load. With the new speed the weights are balanced by the spring in the new position and so maintain the new cutoff.

This governor regulates within a short time and the momentary change in speed due to load being put on or off only slightly different from the permanent one. A hand-wheel is provided at the end of the shaft to enable the engineer to change the speed of the engine by altering the tension of the governor spring while the engine is running.

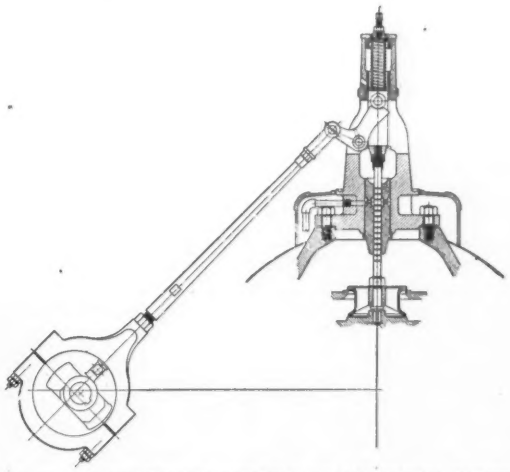


FIG. 5. CONSTRUCTION DETAILS OF ADMISSION VALVE

All joints in the engine are of the metal to metal type, the required tightness being secured by grinding and the workmanship is high grade throughout.

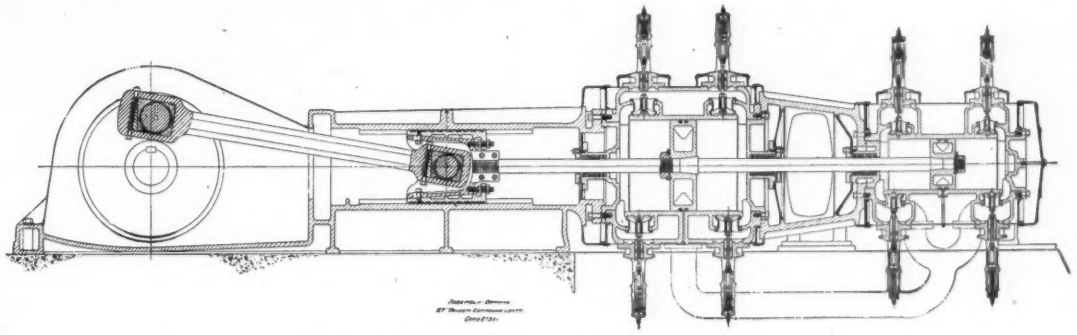


FIG. 2. LONGITUDINAL SECTION OF THE ENGINE

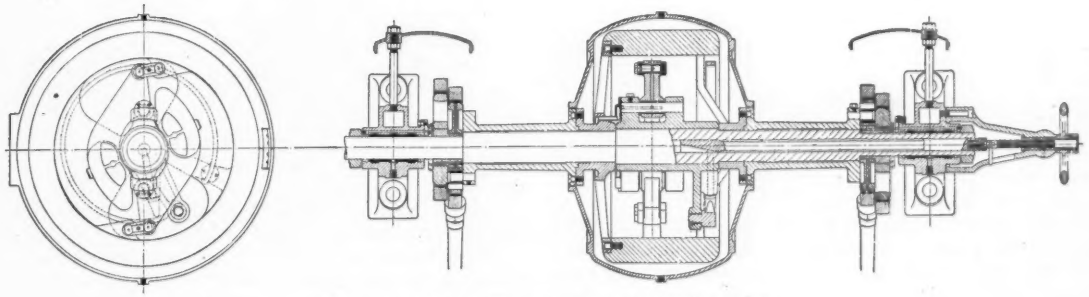


FIG. 3. SECTION THROUGH THE STUFFING BOX

AN EXCELLENT CEMENT for cloth or leather is made by melting together and mixing well the following ingredients in the proportions named: 16 gutta percha and 4 india rubber, cut small, 2 pitch, 1 shellac, 2 linseed oil. —Penberthy Engineer and Fireman.

DOING NOTHING for others is the undoing of ourselves.—Horace Mann.

THE LOCOMOBLE

Compact Arrangement and Prevention of Heat Loss Secure High Economy in Small Units

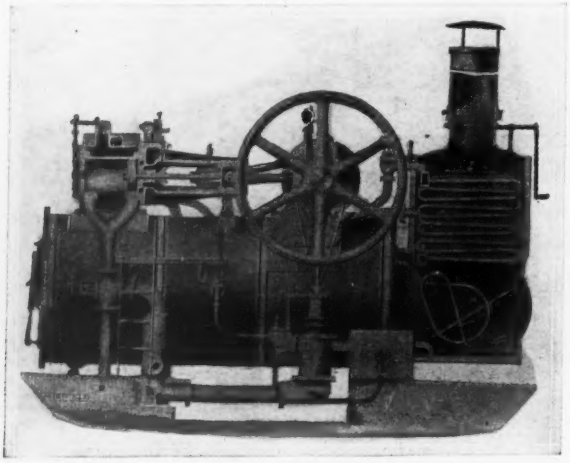
THIS is a development of German origin and its economy in the use of steam would seem to warrant a study of its arrangement to give an idea of how better to arrange power plant machinery.

As it is now built by German manufacturers, the locomobile is adapted particularly for traction and small power plant service. In fact, it is more an economical arrangement than a special engine design.

High and low-pressure cylinders are mounted above the boiler and surrounded by steam domes to which are attached double safety valves. The engine valve is of the balanced piston type with 4 rings, admitting steam from the inside, and particularly adapted to the use of superheated steam. Poppet valves are also sometimes used.

Cutoff is controlled by the governor which is of the shaft type and operates the valve through a shifting eccentric, which can be adjusted on the shaft so that the engine may be made to run either over or under.

The crosshead guide is cast integral with the front cylinder cover, and is bored and faced at one setting which insures alinement.



SIDE ELEVATION OF LOCOMOBILE SHOWING SECTION THROUGH CYLINDER AND SUPERHEATER

Crank shaft bearings are rigidly fixed to the steel saddle which is riveted to the boiler shell, the bearing being in halves, between which an oiling chain is placed which dips into the well beneath the shaft.

Fitting of all reciprocating parts is done while the boiler is under steam, thus doing away with undue strains on these parts when the engine is running.

Water is fed to the boiler by a plunger type feed pump, driven from an eccentric on the crank shaft, and attached to the side of the boiler; it takes water from the source provided, delivers it to the feed-water heater, and thence to the boiler. The feed-water heater is of the tubular type, the water being heated to 150 to 165 deg. F. by the exhaust steam passing through it on its way to the stack. The heater shell is of cast iron fitted with 2 steel tube plates, into which are expanded a number of solid brass tubes, and being of the closed type, no danger from oil in the boiler is encountered.

Lubrication of the valves and cylinders is secured by means of a positive feed oil pump, while all small bearings of the engine are provided with oil cups.

The boiler, which is equipped with strong stays to take the place of foundation frames for the engine, is designed for a working pressure of 170 lb., and has details of construction conforming to the best practice.

It is claimed by the builders that in locomobile type boilers more than half of the evaporation takes place around the firebox roof, and in order to increase the area of the latter it has been made corrugated. One manhole with door is fitted on the boiler barrel in a convenient position to give ready access to the top of the firebox, which, on account of the absence of roof stays, is readily examined and cleaned. Mudholes are provided at the 4 bottom corners of the firebox, also at the top corners of the front plate level with the firebox crown, and at the bottom of the smoke box tube plate.

A superheater is located in the smoke box, the saturated steam passing through a cast-iron header. Small diameter superheater coils of solid drawn seamless steel tubing are staggered in both top and bottom headers, causing the flue gases to be thoroughly broken up among the coils without the use of baffle plates.

Saturated steam enters the upper header and passes into the coils at the top, where the flue gases are coolest. In passing through the coils it comes into contact with hotter gases, reaching the bottom header in a highly superheated condition and is admitted directly to the cylinder. The countercurrent principle enables the greatest amount of heat to be abstracted from the gases, and the superheater coils act also as an efficient spark arrester. The use of a double layer of insulating material on the boiler barrel, smoke box, superheater chamber and the greater part of the external firebox shell adds to the economy of heat. In compound types the steam passing from the high-pressure cylinder to the low is also superheated.

While the locomobile is not built in large units, it gives excellent economy in small sizes due largely to the compactness of design, use of superheated steam and the means employed to prevent loss of heat by radiation and through the stack and exhaust.

Both simple and compound engines are built, the simple type never being equipped with a condenser while the compound type may have either jet or surface condenser. The semiportable and semistationary units being entire plants by themselves, are easily erected on their own foundations.

The test of a compound engine with a brake horsepower of 55.6, running at 201.5 r.p.m., showed the engine developing a brake horsepower-hour on 1.19 lb. coal, the calorific value of which was 14,260 B.t.u. per pound.

The value of superheating is based on the lesser heat conducting capacity and the lesser flow friction of superheated steam; and the consequent smaller loss through heat interchange between the steam and its confining walls is shown in the increase of cylinder efficiency.

None of the equipment of the locomobile is new to the power plant, the exact arrangement is impossible in a large plant but for the small plant it undoubtedly presents unique features which make for economy and a study of these may develop an arrangement for more economical larger plants where the engine and boilers are necessarily separate units.

IN THE COURSE of the taking over of the management of the Nelson Valve Co. by the Yarnall-Waring Co., the latter will remove its offices from 1109 Locust St., Philadelphia, to Chestnut Hill. Both companies will maintain their identities as heretofore, the management and officers of the Yarnall-Waring Co. remaining unchanged.

AUGUSTINE AUTOMATIC ROTARY ENGINE

Augustine Automatic Rotary Engine Co., Buffalo, N. Y.

IN the Augustine rotary engine, shown complete in Fig. 1, the rotating portion is made up of a cylindrical piston, 4 of Fig. 4, which carries sliding blades, 8, moving in and out on roller bearings, 9, in slots in the flanges. The blades are guided by arms, 11 of Fig. 6, which bear in bronze bushings in the compensating balance rings, 12, shown in Fig. 5. These flanges are bolted fast to the piston and have bolted to them the telescopic disks, 18, which fit over the abutment, 3, shown in Figs. 2 and 3. The plates, 10, Fig. 6, close the openings through the telescopic disks.

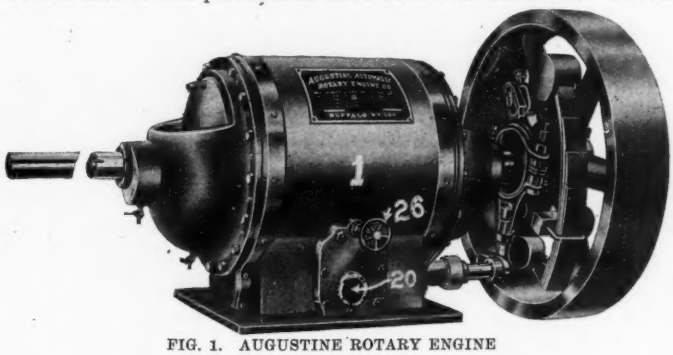


FIG. 1. AUGUSTINE ROTARY ENGINE

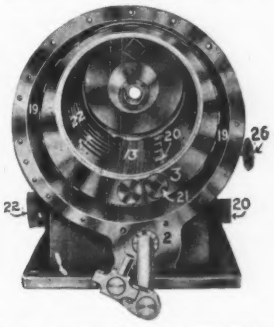


FIG. 2. INTERIOR OF CYLINDER

The entire rotating member is carried on a shaft which runs in the ring bearings, 25 of Fig. 5, these bearings being central with the outer casing. The compensating rings, 12, are so arranged as to balance the centrifugal force of the blades, thus keeping the rotor steady at all times, and they also serve by their positions in the grooves, 23 of Fig. 5, to move the blades in and out in the grooves of the flanges, so that they are kept bearing against the cylinder walls at all times, with a packing strip along the edge to make a steam-tight joint.

The cylinder, which is mounted in the abutments, 3, eccentric to the casing, provides the means for expansive working of the steam. Steam is admitted through the pipe, 20 of Fig. 1, and is controlled by a Corliss type valve, 6 of Fig. 6, operated by a rocker arm and eccentric, the eccentric position being controlled by an inertia shaft governor.

The piston makes contact with the cylinder on the priming pockets, 13, being held there by the bearings, 25. As the blade passes the admission ports, 20, Fig. 2, the admission valve is wide open, and steam is admitted behind the blade, forcing the piston forward until cutoff occurs, that point being controlled by the governor according to the load. Steam then expands behind the blade, forcing the piston forward until it reaches the exhaust port, 22 of Fig. 2, when release occurs.

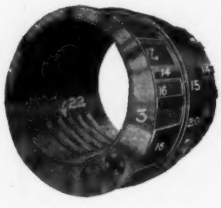
Pressure is equallized between the cylinder and the inside of the telescopic disks through the small ports, 17 of Fig. 3, and small check valves. The pockets, 16, are thus filled at all times with steam of the same pressure as that in the cylinder, and this bearing against the inside of the telescopic disks gives a floating bearing.

Oil is also forced out through these ports 17 by centrifugal force, and lubricates the running joint between the telescopic disks and the ribs, 14. The ends of the telescopic disks make a tongue and groove joint with the center ribs, 15, Fig. 3, of the abutment, thus preventing leakage. The flanges bear against the ends of abutment 3, making a running joint by means of packing rings. The piston, therefore, rotates inside the cylinder, the flanges rotate against the ends of the abutment, and the telescopic disks rotate in the space 19 of Fig. 2.

The endwise pressure is taken by the flanges, which bear against the telescopic disks, so that no pressure comes against the heads 5 of Fig. 5. As the steam is swept from the admission port around to the exhaust port without reversal, the result is a "uniflow" effect, and the exhaust steam is never carried backward over the cylinder surfaces.

By this construction, the Augustine engine gets full steam pressure into the cylinder through a large steam port area, with small clearance and short valve travel. The steam valve closure is quick, and a large exhaust port area is obtained without the use of a valve. The engine can run at high or low speed, with high or low steam pressure, and as there is no compression, water entering the cylinder, does no damage.

The compactness of the engine is shown by the fact that a 41 brake horsepower engine has over all dimensions 48 in. long, 17 in. in diameter of casing, and 20 in. high. It weighs 800 lb., and tested at 100 lb. boiler pressure, gave a steam consumption of 36½ lb. per brake horsepower per hour.



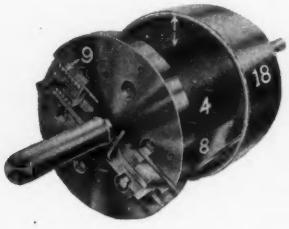
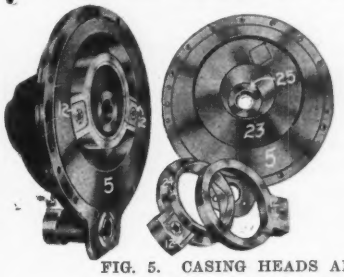


FIG. 3. CYLINDER AND ABUTMENT
FIG. 4. ROTOR SHOWING PISTON BLADES



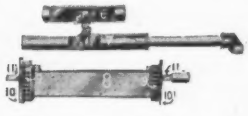


FIG. 5. CASING HEADS AND BALANCING RINGS
FIG. 6. PISTON BLADE, VALVE AND ROD

COMPOUNDING THE ENGINE

Thus Reducing the Largest Loss by 10 to 30 Per Cent, and Evening Up the Turning Moment. How to Determine the Proper Cylinder Volumes and the Right Receiver Pressure for a Given Set of Conditions.

WERE THERE NO HEAT LOSS in the steam engine, there would be no reason for compounding which would be sufficient to warrant the expense. The chief reason for compounding is in order to reduce the range of temperature between initial and exhaust pressures in any one cylinder so that the condensation of entering steam will be lessened. There is also a slight gain in compounding, because the clearance volume in the high-pressure cylinder is less than it would be if only the larger cylinder were used, but this is not sufficient to warrant the expense of the extra cylinder. Also, the division of load between 2 sets of reciprocating parts and cranks equalizes the turning moment on the shaft, and makes it possible to get steadier speed with a lighter flywheel. There will be some gain as to leakage also, past piston and valves, because of the

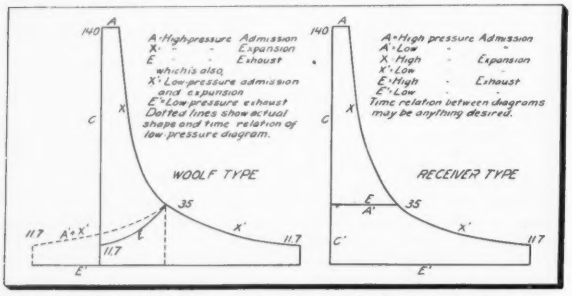


FIG. 1. THEORETICAL DIAGRAMS OF COMPOUND ENGINE ACTION FOR WOOLF AND RECEIVER TYPES

less difference in pressure between initial and exhaust steam, and also any steam which leaks by in the high-pressure cylinder is used expansively to do work in the low-pressure.

As a rule the condensation loss is greater in the high-pressure cylinder than in any of the others and in any case the condensation in other cylinders is of steam already partly used. Comparison is therefore made herewith of the loss in the high pressure cylinder for triple, compound and triple expansion engines, at different degrees of cutoff.

Per Cent Condensation Loss in High-Pressure Cylinder

Per cent Cutoff	Simple	Compound	Triple
5	42	..	..
10	34	26	..
15	29	24	22
20	26	22	20
30	22	18	16
40	18	15	13
50	14	12	10

The Ashcroft Mfg. Co. gives as the comparative steam consumption per horsepower-hour at 100 lb. pressure, and cutoff at 30 per cent of the stroke, for noncondensing, simple engines, 24.7 lb.; for simple condensing engines, 18.74 lb.; for compound condensing engines, 14.21 lb.; and for triple expansion condensing, 12.5 lb. The differences between these measure the gain in effectiveness of each type over another.

Dividing the Load

THE division between cylinders is primarily one of temperature range, and these ranges should be in inverse proportion to the condensing surface up to cutoff; practical considerations, however, dictate either equal total pressure on the pistons, or equal work in the different cylinders. In making preliminary calculations, it is usual to make the expansion ratios in the 2 cylinders somewhere near equal, and this usually gives reasonably good proportioning of cylinders for equal work.

Comparison of Expansions, Temperature Ranges, Power Developed and Total Pressures in Engines of Common Ratios (Weightman)

	Simple	Compound High	Compound Low	Triple High	Triple Int.	Triple Low
Diam. in	60	33	61	28	46	61
Volume ratio	....	1	3.4	1	2.7	4.74
Expansion ratio	20	5	4	2.74	2.71	2.71
Initial press. abs.	165	165	33	165	61	22
M. E. P. lb.	29	53.1	15.7	60.6	22.3	12.5
Temp. Range Deg	182	106	176	72.5	59.4	50
Hp. Developed	800	399	403	269	268	264
Total initial press	455,218	112,900	84,752	64,162	63,817	53,773

For a compound engine, evidently the volume at the end of expansion in the low pressure cylinder will be that at the end of expansion in the high-pressure, times the ratio of cylinder volumes. The table herewith gives a comparison of expansions, temperature ranges, developed horsepowers and total pressures, for

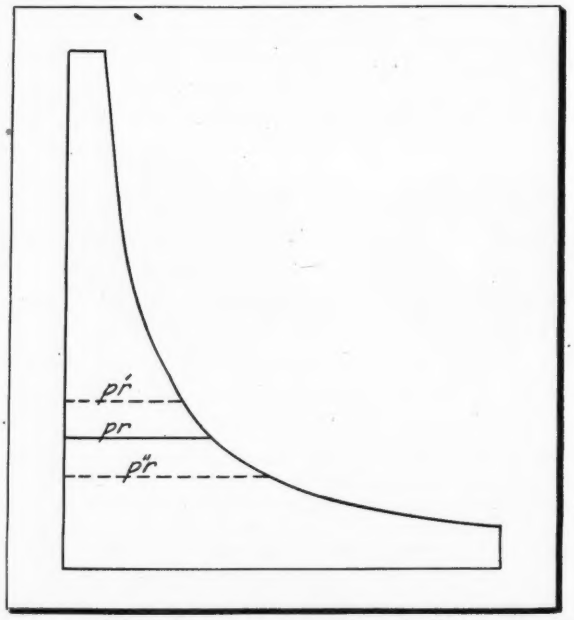


FIG. 3. EFFECT OF CHANGE IN LOW-PRESSURE CUTOFF ON RECEIVER PRESSURE AND DISTRIBUTION OF WORK

engines with 2 or 3 cylinders of common dimensions. In case of a triple-expansion engine, the ratio of expansion in the high-pressure cylinder is the ratio of the total cylinder volume to the cutoff volume; in the

intermediate cylinder, it is the ratio of the intermediate volume to the high pressure volume; in the low-pressure cylinder, the ratio of the low-pressure volume to the intermediate volume, no drop being considered between cylinders. The total expansion in a triple will be the continued product of the expansion ratios of the 3 cylinders.

Woolf and Receiver Types

TWO general types of compound engines are recognized, the Woolf which sends the steam direct from one cylinder to the next, and the receiver type, which has a reservoir between cylinders. The Woolf type can be used only for cranks set at 180 deg. apart,

FIG. 2. RATIO OF CYLINDER VOLUMES TO HIGH-PRESSURE CYLINDER. TERMINAL PRESSURE = ½ LB. FOR NON-CONDENSING; = 6.5 LB. FOR CONDENSING

Gage Pressure lbs.	Compounds				Condensing	
	Noncondensing		Compound		Triple Expansion	
	Ratio Exp.	Lowpres. Vol.	Ratio of Expansion	Low pres. Vol.	Intermediate Vol.	Low pres. Vol.
80	6	2.2	14.6	3.35	.....	.....
90	7	2.4	16.2	3.50	.....	.....
100	7.7	2.5	17.6	3.70	.....	.....
110	8.3	2.7	19.2	3.90	.....	.....
120	9.0	2.8	20.6	4.00	2.40	6.6
130	9.7	2.85	22.3	4.10	2.50	6.8
140	10.3	2.95	23.9	4.30	2.55	6.9
150	11.	3.05	25.4	4.40	2.60	7.1
160	11.6	3.1	26.8	4.55	2.65	7.2
170	12.3	3.2	28.6	4.70	2.7	7.35
180	13.	3.3	30.0	.....	2.75	7.45
190	13.6	3.4	31.5	.....	2.78	7.60
200	14.3	3.5	33.1	.....	2.84	7.70

or together, while the receiver type is available for engines and cranks set at 90 and 120 deg. There is always a certain amount of drop between cylinders in either case, this being usually larger in the receiver type.

Considerable variation may be allowed in the ratio of cylinder volumes without greatly affecting the economy of the engine, but, for noncondensing engines particularly, a wide fluctuation of load seriously increases the steam consumption so that the compound engine is not well adapted for a widely varying load when used in noncondensing form.

Ratio of Cylinders

FROM comparison of a number of authorities and a number of engines, it is found that for noncondensing compound engines a good ratio of cylinder volumes is equal to $0.92\sqrt{r}$, and for condensing compound is equal to $0.88\sqrt{r}$, being the ratio of the initial pressure to the terminal pressure in the entire engine. For triple-expansion engines, like comparison gives as the ratio of the intermediate volume to the high-pressure, $0.88\sqrt[3]{r}$, and for the ratio of low-pressure volume to high-pressure, $0.24\sqrt[3]{r}$, being as before the ratio of the intial pressure in the high-pressure cylinder to the terminal pressure in the low-pressure cylinder. Based on these values the accompanying table, Fig. 2, has been computed which represents reasonably well average American practice. As noted in this table, the terminal pressure has been taken as ½ lb. gage for noncondensing engines, and 6½ lb. absolute for condensing engines. These are as low as would ever be profitable to use, and in case the teminal pressure is taken as higher, the ratios of volumes would be somewhat decreased.

Receiver Volume

EXAMPLES of the arrangement of compound engines are shown in the commercial descriptions of both high speed and 4-valve types. The tandem arrangement corresponds to the Woolf classification, and the cross-compound is usually arranged with cranks at 90 deg., in order to avoid dead centers. In the triple-expansion engines, the cranks are frequently arranged at 120 deg., and in this case a small receiver can be

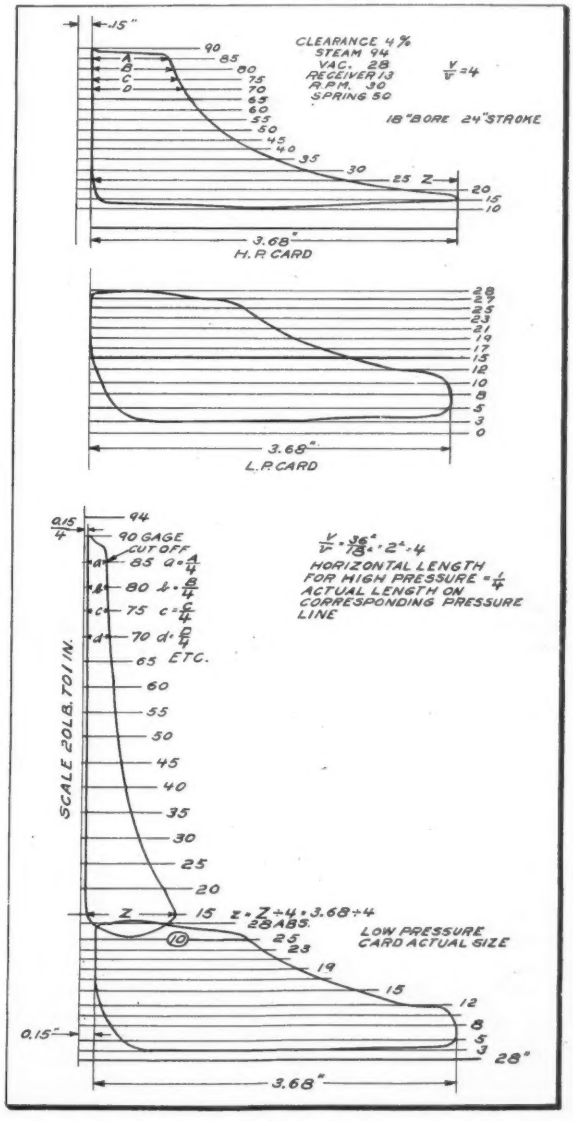


FIG. 4. COMBINING CARDS FOR COMPARISON WITH THE THEORETICAL EXPANSION

used as the inlet and out-take of steam are distributed throughout the revolution. When the arangement of cranks is at 180 deg., and the receiver is used, it is ordinarily made the same volume as the high-pressure cylinder; when the crank arrangement is 90 deg., the receiver volume should be 1½ times that of the cylinder exhausting into it. For 120 deg., it may be made smaller.

Power and Cylinder Sizes

IN deciding on the sizes of cylinders for a compound engine, the first one to determine is the low-pressure cylinder. This must be large enough to develop the entire power required, taking initial and terminal pressures the same as for the entire 3 cylinders, and figuring exactly as for a simple engine. Terminal pressure is usually taken from 6 to 9 lb. condensing, or from ½ to 2 lb. noncondensing, and the ratio of diameter to stroke for the low-pressure cylinder is taken from 1 to 1½.

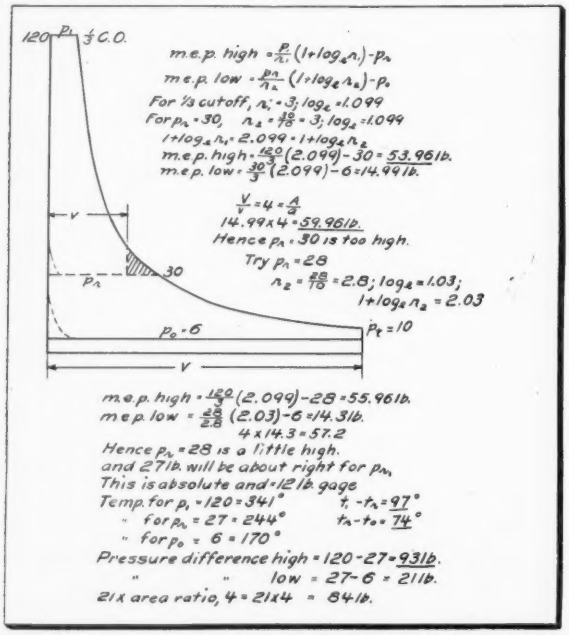

120
p_1
⅓ C.O.
m.e.p. high = $\frac{p_1}{r_1}(1+\log_e r_1) - p_0$
m.e.p. low = $\frac{p_1}{r_2}(1+\log_e r_2) - p_0$
For ⅓ cutoff, $r_1 = 3$; $\log_e = 1.099$
For $p_1 = 30$, $r_2 = \frac{30}{18} = 3$; $\log_e = 1.099$
$1+\log_e r_1 = 2.099 = 1+\log_e r_2$
m.e.p. high = $\frac{120}{3}(2.099) - 30 = 53.96$ lb.
m.e.p. low = $\frac{30}{3}(2.099) - 6 = 14.99$ lb.
$\frac{V}{v} = 4 = \frac{A}{a}$
14.99 x 4 = 59.96 lb.
Hence $p_1 = 30$ is too high.
Try $p_1 = 28$
$r_2 = \frac{28}{18} = 2.8$; $\log_e = 1.03$;
$1+\log_e r_2 = 2.03$
p_1
30
$p_0 = 6$
$p_t = 10$
v
V
m.e.p. high = $\frac{120}{3}(2.099) - 28 = 55.96$ lb.
m.e.p. low = $\frac{28}{2.8}(2.03) - 6 = 14.3$ lb.
4 x 14.3 = 57.2
Hence $p_1 = 28$ is a little high.
and 27 lb. will be about right for p_1
This is absolute and + 12 lb. gage
Temp. for $p_1 = 120 = 341°$ $t_1 - t_2 = 97°$
" for $p_2 = 27 = 244°$ $t_2 - t_0 = 74°$
" for $p_0 = 6 = 170°$
Pressure difference high = 120 - 27 = 93 lb.
" " low = 27 - 6 = 21 lb.
21 x area ratio, 4 = 21 x 4 = 84 lb.

FIG. 5. FIGURING THE RECEIVER PRESSURE FOR EQUAL WORK IN COMPOUND CYLINDERS

In finding the actual horsepower that the engine will develop, a diagram factor must be taken into account, to allow for the rounding of corners and for drop between cylinders. This will usually be about 0.75 for a triple-expansion engine, and 0.8 for a compound.

Receiver Pressure

THE effect of change of receiver pressure on the distribution of load between the cylinders is plainly seen by reference to the theoretical card for the combined engine, Fig. 3. In this the normal receiver pressure is shown by the full line marked pr., and the effect of shortening the low-pressure cutoff, as shown by the upper dotted line, is to raise the receiver pressure and the corresponding back pressure of the high-pressure cylinder, and, therefore, to thrown a larger part of the work into the low-pressure cylinder. On the other hand, lengthening the low-pressure cutoff, lowers the receiver pressure and throws a larger part of the work upon the high-pressure cylinder. In no case should the receiver pressure be over half the boiler pressure, and the exact value is usually chosen to give equal work in the 2 cylinders.

Combined Diagrams

IN order to compare the work of a compound engine with the theoretical card for a single cylinder working under the same conditions, it is necessary to combine the high and low-pressure cards into a single diagram. This is done by first copying the low-pressure card, usually at its actual size, and at a distance from the clearance line representing the clearance of the low-pressure cylinder. The high-pressure card is then drawn in, reducing the volume of length of the card to the same scale as the low-pressure card, that is, shorten the horizontal lines in proportion to the ratio of cylinder volumes. The card is set off from the clearance line by a distance representing the high-pressure clearance volume, on the reduced scale, so that it may correspond with the low-pressure card as to the expansion line. A pair of cards from a compound engine and the combined diagram derived from them are shown, illustrating clearly the method, Fig. 4.

Equalizing Load

IN order to determine the receiver pressure which will equalize work in the 2 cylinders, it is necessary to make a trial computation, and then usually make a second assumption. The mean effective pressure in the high-pressure cylinder is found by multiplying the initial pressure by 1 plus the hyperbolic logarithm of the ratio of expansion in the high-pressure cylinder, dividing by the ratio of expansion in the high-pressure cylinder, and from the quotient subtracting the receiver pressure. The mean effective pressure in the low-pressure cylinder is found by multiplying the receiver pressure by 1 plus the hyperbolic logarithm of the low-pressure expansion ratio, dividing by that ratio, and subtracting from the quotient the back pressure in the low-pressure cylinder. For equal stroke, these 2 mean effective pressures should be inversely, as the squares of the cylinder diameters if work is to be equally divided.

It is necessary to make an assumption as to what the receiver pressure should be, knowing the initial pressure in the high-pressure cylinder and the exhaust pressure in the low-pressure cylinder, and find out how the mean effective pressures work out; the second assumption of the receiver pressure will usually give nearly enough the desired value for all practical purposes. The process is shown in the accompanying example, Fig. 5. If it is desired to test the temperature ranges, find the temperatures corresponding to initial pressure in the high-pressure cylinder, receiver pressure, and back pressure in the low-pressure cylinder, from the steam table, and from these compute the temperature ranges in the high and low pressure cylinders, or for a triple expansion engine, find the 2 receiver pressures and temperatures and compute the 3 temperature ranges for different cylinders. These should be somewhere nearly equal or should be somewhat lower for the intermediate and low-pressure cylinders than for the high-pressure.

To get the total pressures, on pistons, multiply the difference between initial and exhaust pressures in each cylinder by the area of the piston; the total pressures in all cylinders should be reasonably near equal.

Proportioning of parts for compound engines is done on the same basis as for simple engines, with the exception that the steam ports have the velocity somewhat increased for the intermediate and low-pressure cylinders, and parts for the low-pressure may be somewhat lighter than for a simple engine with the same size cylinder. In the high-pressure cylinder, the steam velocity in the admission ports may be 100 ft. a second, and in the exhaust ports, 90 ft. a second; for the intermediate cylinder, the velocity in the steam ports may be 180 ft. a second, and in the exhaust ports, 120 ft.; for the low-pressure cylinder, velocity in the steam ports may be 250 ft. a second, and in the exhaust ports, 140 ft.

GOVERNING THE STEAM ENGINE

Control of the Steam Supply, Classes of Mechanism Used and Means of Regulating, Effect of Changing Lead and Travel of Valve

POWER DEVELOPED BY an engine may be altered by changing either the initial pressure or the point at which the engine cuts off. In the former case we take off from the top of the diagram as shown in Fig. 1A, and in the latter method the expansion area is reduced as shown in Fig. 1B.

This divides governors into 2 classes according to the general method of working; the throttling, and the cutoff. The throttling type is uneconomical, for the steam must be made at a high pressure and used at a lower pressure, thus cutting down the possible efficiency of the cycle, and the same amount of steam is used each stroke whether the engine is carrying heavy load or light. Throttling is, therefore, confined for the most part to cheap and less efficient engines where fuel cost is not of consequence, or where the steam needed for other purposes is more than that needed for power so that the engine is used as a reducing valve.

For varying the cutoff, 2 methods are used, that of detaching the valve from the eccentric and closing it by a spring or dashpot; and that of shifting the eccentric as to lead or travel or both. In the first method, the governor controls the point at which the valve is released from the eccentric; in the second method, the eccentric is either turned around the shaft as in the Buckeye or swung across the shaft on a pivot pin as in the Rites and Armstrong governors shown in the engine descriptions.

As the detaching governor acts only on the cutoff, it alters no other event in the card; this has certain advantages, but the mechanism limits it to low and medium speed engines. The eccentric turned about

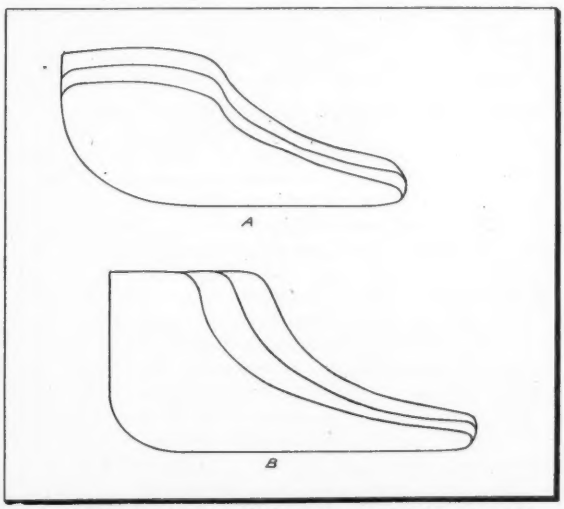


FIG. 1. CHANGES OF DIAGRAM FROM GOVERNOR CONTROL; A, FOR THROTTLING; B, FOR VARIABLE CUTOFF

the shaft changes the cutoff and also all other events of the stroke by the same amount if the governor acts on the main valve, as shown in Fig. 3A. It is desirable that the exhaust and compression be altered but little, hence this method is used mostly to control riding cutoff valves through the cutoff eccentric, the main eccentric being fixed.

The swinging eccentric can be so pivoted that it will increase the travel of the valve and thereby lengthen the cutoff, and at the same time it may increase or decrease the lead at the will of the designer. As a matter of fact, it is desirable to have the lead decreased as the cutoff is shortened in order to avoid overspeeding the engine at no load. The action of the swinging eccentric may be summarized as follows:

Increasing travel gives: earlier admission, later cutoff, earlier release, later compression. Lead may be altered to bring all events a little earlier or a little later, the former being generally used.

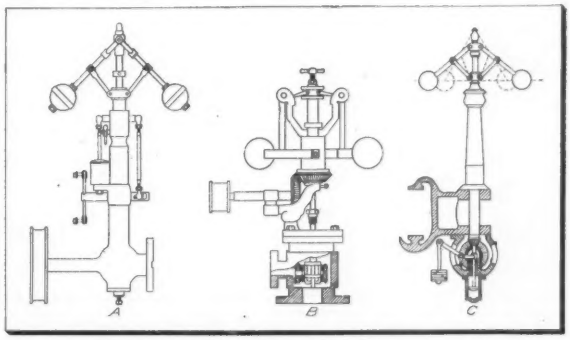


FIG. 2. FORMS OF FLYBALL GOVERNOR; A, GRAVITY; B, SPRING; C, WEIGHTED

Decreasing travel gives the opposite effect on each event of the stroke.

Fig. 3B shows the effect on admission and cutoff of the swinging eccentric. E′ is the eccentric circle at short travel, C the crank circle, 1 the eccentric position at admission when the valve has been moved from midposition by the amount of the lap, OL. I is crank position at admission and P the corresponding position of the governor pivot pin. With this eccentric travel, the angle 10I between the crank and eccentric will remain constant, hence when the eccentric has moved to open the valve and reached 1′ at which the valve is just closed, the crank will be at I′, the cutoff position.

If from the point P the eccentric center is swung out into the circle E^2, it will be at x and the new angle between eccentric and crank will be xoI. But admission takes place when the eccentric is at 2, and the valve has moved a distance OL from its midposition, hence the crank will be at II, angle 20II being equal to xoI. Cutoff will be with crank at II′, angle 2′oII′ being equal to 2oII.

The effect on exhaust events may be shown in a similar manner.

Mechanical Details

AS to operating mechanism, governors divide into 2 classes, the flyball and the shaft. In most Corliss designs, the flyball has the centrifugal force of the balls working against gravity, but for higher speeds or more sensitive regulation, or for other than vertical positions, the spring is substituted.

The speed at which a governor will run is controlled by the height of the cone of revolution, that is, the vertical height from the center of the balls to the point of suspension. Adding to or taking from the weight of the balls, so long as there is no other weight to lift, will not affect the speed at which a governor

or flyball gravity type will take a given position. In the case of a spring resistance, the heavier the ball, the farther out it will go for a given speed.

It is desirable to have heavy weight in the governor to give power so that it can move the valve gear easily and quickly. Heavy balls are not advisable for they bring great strains on the supporting links, unless they are run at slow speed when they loose sensitiveness to change in the engine speed. Extra weight can be put on the spindle and lifted by the balls, thus allowing of small balls run at high speed, giving sensitiveness and a powerful governor; and also the speed at which the governor will control the engine can be regulated by the amount of the extra weight.

Different engines show this extra weight as a counterweight between the links which carry the flyballs or as carried on a pan at the bottom of the spindle.

When used for throttling control, the flyball governor

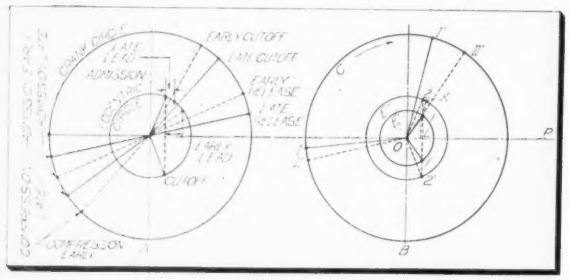


FIG. 3. DIAGRAMS OF ACTION OF SHAFT GOVERNORS; A, CHANGING THE LEAD BY ROTATING THE ECCENTRIC; B, CHANGING THE TRAVEL BY SHIFTING THE ECCENTRIC

is usually of the spring resisted type, and is directly connected to a balanced poppet valve located between the stop valve and the steam chest. Change of speed is secured by changing the tension of the spring, or by altering the length of the spindle to the poppet valve while the engine is running. Here, as before, small balls at high speed give a sensitive governor, but heavy balls give power, so that it is sometimes best to use a counterweight as well as the springs to oppose the centrifugal force of the balls. As this type is used more for small engines, the extra weight is not often needed.

Shaft Governors

ALTHOUGH the details of shaft governors vary widely, they may be classed as those which use centrifugal force only, and those in which this effect is combined with inertia. As a rule, the centrifugal governors are used where the eccentric is revolved around the shaft, controlling a riding cutoff valve.

For controlling the valve of a single valve engine, power is required, which means a heavy governor weight, and it is found best to take advantage of the inertia of this weight to increase the quickness of action. Two typical forms are most largely in use, the Rites and the Armstrong. The former uses a heavy bar and a coiled spring; the latter a weight on the end of a leaf spring for the centrifugal force, and frequently an additional bar to increase the inertia effect. The action of the governor is fully explained in the article in this issue by Sterling H. Bunnell, as is also the matter of adjustment of the Rites governor.

In any form of shaft governor, changing the spring attachment changes the sensitiveness, and changing the weight adjustment changes speed. In the centrifugal form, increasing the spring tension and the weights will increase sensitiveness, or attachment of springs or weights may be moved so as to give them greater arm about the pins, which will have the same effect as increasing the tension or weight. Increase of weight alone, or decrease of spring tension alone will reduce the speed, or the same effect may be produced by giving the weight greater leverage, or the spring less. This change of leverage will, however, change the sensitiveness rapidly, and the effect should be carefully studied.

The Armstrong governor is so arranged that change in spring tension changes the speed and change of the connection to the eccentric link changes the sensitiveness. It is not often necessary to change the weights, but if it is needed, the same principles apply as for the Rites, especially if an extra inertia bar is used.

ADJUSTING THE RITES GOVERNOR

Simple Methods for Controlling Sensitiveness and Close Regulation of Shaft Governors. Where to Look for Causes of Trouble.

By Sterling H. Bunnell

ENGINES with inertia type shaft governors can be adjusted to control the speed within less than one revolution range, and, in fact, if desired, a shaft governing engine can generally be adjusted to run even faster at full load than under light load. While this condition is not desirable for general purposes, the fact that it can be obtained is an indication of the remarkable accuracy which inertia shaft governors can attain.

One leading shaft governor, which consists of a single bar of cast iron, hung on a single heavy pin, and carrying attached to itself the pin or eccentric that drives the valve gear, was invented by Francis M. Rites, and bears his name throughout the trade. The accompanying illustration shows a common form of the Rites' governor, in which the single arm is widened at its extreme ends into flat weights.

Principles of Action

BEING hung by a pin with its center at one side of the center line of the arm, revolution of the governor with the wheel causes the development of a centrifugal force which opposes the tension of the spring, and which causes the center of gravity of the governor arm to swing outward from the center of the governor wheel toward the rim. This movement of the arm is accompanied by a turning movement, by which the short or heavier end of the arm retreats against the direction of the motion of the engine, while the long or light end carries the valve rod pin or eccentric center inward and toward the crank which is about 10 deg. behind the center line on which the pivot pin is located.

The Rites' governor is designed so that the centrifugal force of the governor arm at the desired speed of operation will balance the tension of the spring, and therefore maintain the location of the center of the eccentric pin at a definite position for each speed of revolution within the range of the governor's action. Thus, if the engine is designed to operate at 200 r.p.m., the tension of spring and weight of arm are so adjusted that the governor arm will take its extreme outward position when the engine is running

at about 201 r.p.m., at which time the steam valve travel is shortened so that no admission of steam occurs; while at a speed of 199 r.p.m., the governor arm is in the inward position, at which time the valve has its greatest travel, and the steam is cut off at the greatest length permitted by the valve gear pin.

Increase of speed of the wheel carying the shaft governor has the effect of momentarily leaving the governor arm behind, by which action the valve gear pin moves toward its innermost position and shortens the travel of the valve. On the other hand, a decrease in speed causes the governor arm to over-run the engine, carrying the valve gear pin backward and outward, and delaying the steam cutoff, thus cooperating with the centrifugal force, but acting almost instantaneously.

After each such momentary change the governor arm quickly assumes the exact speed of the engine, and balancing its centrifugal force against the tension of the opposing spring, sets the valve gear pin to just the point required to carry the load on the engine, whatever that load may be. Within the entire range of action of the governor from no load to full load, the governor assumes a fixed definite speed for each load, the speed being slightly greater for light loads, and slightly less for heavy loads.

While the action of a well adjusted governor is almost magically perfect, the misbehavior of a governor which is out of order is almost magically unexplainable. The simplicity of the governor makes it evident that there are but few possible causes of derangement, and a careful study of the conditions will invariably disclose the cause of the trouble and point out the remedy.

When Looking for the Trouble

WHEN it becomes necessary to adjust a Rites' shaft governor, the first thing to be done is to find out just what its effect is on the speed of the engine. No time should be wasted, therefore, in trying experiments with the governor until the effect on the engine under various changes in load is understood beyond question. If the engine is running well enough so that it can be allowed to run for a while, take a position at the switchboard and watch the voltmeter and ammeter carefully to determine the effect of a change in load on the speed of the engine and generator. An increase in amperage may cause a permanent decrease in voltage, in which case a decrease in amperage will probably cause a corresponding increase in voltage. This indicates that the engine drops off too much in speed under increase in load, and speeds up too much under a decrease in load; in a word, that the governor is insensitive.

It may be found, however, that on decrease in load, the voltage rises only momentarily and drops back close to normal. This action is always to be expected, but the change should be confined in narrow limits.

If on an increase in load the voltage rises excessively, and then drops back after 2 or 3 seconds, it is evident that an increase in load causes the governor to "dig into the load," as engineers say, that is, to swing too far before regaining control of the engine. This particular condition usually is accompanied by great irregularity in speed, the engine running first fast and then slow on the least disturbance, showing that the governor is hunting. The opposite difficulty to this is when the engine drops off in speed upon increase in load and recovers but slowly. Similarly, a decrease in load will probably cause a considerable increase in speed, followed by a slow return to normal. In this case the governor is evidently slow in action, though accurate enough as to speed, since after the governor has had time to adjust the eccentric, the speed is eventually controlled.

It may take a long time to determine the exact effect of increase or decrease in load, if the engine must be continuously operated, and the adjuster must wait for casual load conditions to bring about the change he is waiting to observe. If, however, the engine can be taken out of service, a simple plank brake put under the flywheel and operated by 1 or 2 men, provides all necessary means for loading the engine and increasing or decreasing the load instantly at the word of command. A few minutes with the plank brake will do more in investigating the real conditions under which the governor acts, than a whole day spent in watching the switchboard.

To Get the Speed Right

AFTER the behavior of the governor has been fully studied, the proper change to make in the action of the governor is to be determined. In the first place, give the engine about ¼ load, by means of the switch-

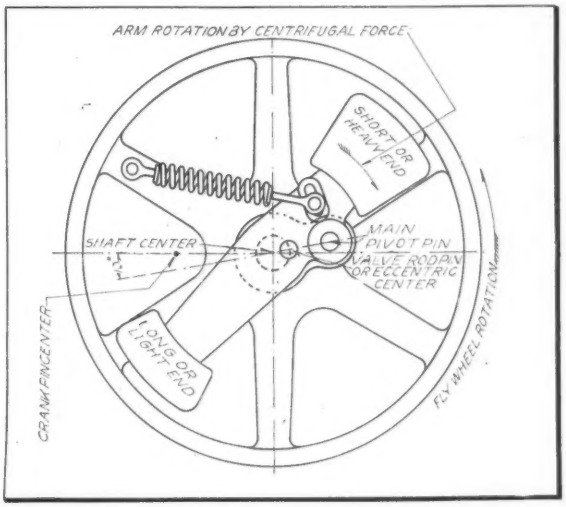


FIG. 1. POSITION OF RITES GOVERNOR PARTS WITH SHORTEST VALVE TRAVEL AND GOVERNOR ARM FARTHEST OUT

board, or by the plank brake, and adjust the governor spring, if necessary, to bring the speed about right. If it happens that the tension screw of the spring has strained the spring to its limit, cut off one or more coils of the spring, or if there are loose weights attached to the short end of the governor arm, take these off. If in making speed trials for this purpose, the speed is found to be irregular, look for a cut bearing or bushing on the main governor pin, which carries the arm. A dry or scored pin naturally causes the arm to stick fast, or to move jerkily under changes in speed.

To Get the Regulation Wanted

HAVING made sure that the governor arm moves freely on its pin and that the engine speed is about right with ¼ load, increase the load to ¾ or full load and observe whether the speed drops too much for satisfactory regulation. If the engine runs more than 1 to 1.5 per cent slower under full load than under ¼ load, the spring, while at the right tension, is too

stiff. This fault may be overcome as follows, without changing the spring.

The pin to which the spring is attached to the governor arm, is carried in a slot formed in the arm, and moving the pin inward along the slot, that is, toward the main governor arm pin, has the same effect as substituting a lighter governor spring. If, therefore, the speed drops too much with increase of load, set the spring pin inward along its slot.

Another way of producing a corresponding effect is to remove any weights that may be attached to the short end of the governor arm, and then to slacken the spring until the speed at ¼ load is correct, and again observe the effect of the increased load.

Still another way, is to add a weight to the long arm on the side toward the spring. The same effect is produced by shifting any loose weight which may be attached to the short end, toward the pivot side of the arm; but the effect of such a change is inconsiderable.

Tight Valve or Packing

IF none of these simple changes correct the fault of excessive drop in speed under increased load, look for a hard pulling steam valve. The pressure plate may be fitted too close to the valve, or the valve may have run dry and started to cut, or the stuffing box packing may be too tight. Any undue strain on the valve gear adds its effect to the spring tension, and causes the engine to run faster than it otherwise would; but the same effect may become less important as the load increases and thus allow the engine to drop in speed under increased load.

In setting the governor for close regulation, note that some drop in speed is necessary to prevent racing, for if a governor is too sensitive, the engine is always likely to run away momentarily, or to seesaw in speed after each sudden change in load. Particularly with alternating-current generators it is best to have the governor well on the insensitive side, permitting a considerable decrease in speed under increased load. A variation of 4 or 5 per cent between no load and full load may not be too great for alternating-curre full load may not be too great for alternating-current generators operating in parallel on power service, as

Overspeed at No Load

IF the engine operates under conditions which may cause the sudden throwing off of the entire load, the governor should next be tried under full steam pressure and no load. Under this condition the steam valve is moving just the length of its lap, so that the steam port should not open at either end of the stroke. It may be, however, that the lead is great enough to allow a little steam to enter just before the piston reaches the end of the stroke, and expanded behind the piston, to cause the engine to run over speed. A similar effect is produced, if the steam valve leaks; or if the lap is too short. The only way to correct this difficulty is to decrease the travel of the valve, or provide a new steam valve a little longer than the old one. The valve travel can be conveniently decreased by making and putting in an eccentric valve gear pin, which being turned slightly in its hole in the governor arm will carry the center of the portion which engages the valve rod a little nearer the center of the governor wheel and so decrease the travel of the valve.

Condensing engines in particular are likely to overrun their normal speed when all load is thrown off, because the trifle of steam admitted behind the piston expands against the vacuum and produces a greater power than it would under noncondensing conditions. It is best not to require the speed to be limited too closely under no load; no possible harm is done if the engine runs several revolutions faster under no load than under any light working load; while decreasing the load or increasing the lap enough to prevent any admission of steam under these conditions, has the effect of decreasing the lead of the valve at other cutoffs as well, and therefore of giving a late admission under normal working conditions.

Adjusting for Inertia

HAVING thus adjusted the engine to run at normal speed with ¼ load, a little slower with full load, and not too fast with no load at all, the next thing is to observe the steadiness of the speed under a change of load. The degree of steadiness is obtained through the inertia effect of the governor. If, after a sudden decrease of load, the engine speeds up momentarily and promptly returns to normal speed, the governor is operating in a satisfactory way. If the increase in speed is sudden and the return too slow, or if after an increase the engine returns to normal speed, falls below normal, again speeds up above normal, and so after two or more swings returns to its correct speed, the inertia effect of the governor is too little. These swings are most easily seen by watching the voltmeter of a direct-connected generating outfit; but they can be observed by a tachometer applied to the engine shaft, if the other method is not available.

If the engine accordingly makes too many swings above and below speed before finally settling to its normal, a weight should be attached to the long end of the governor arm. If the governor is too slow in catching the engine after a change in load, even though the speed then returns to normal without being followed by one or more excessive swings, the same remedy should be applied, that is the addition of a weight on the long end.

Pivot Pin Friction and Gravity Effect

IF the action of the governor is irregular, so that the changes of speed are not definite and uniform under similar changes in load, the governor pin will probably be found dry or sticking; or the pin may be found entirely too loose, needing a new bushing. One peculiar effect which has been known to exist, is the weight of the valve gear parts timed so closely with the tendency of the governor arm to fall forward and backward alternately with each revolution of the engine, as to introduce a decided "kick" in the governor arm and cause the most unaccountable speed variations. A tendency to swing up and down in speed, or to change speed irregularly, can sometimes best be corrected by the addition of a simple brake, formed of a piece of steel, or a wooden block pressed against the governor arm by a short spiral spring, or some similar rubbing device. Brakes are particularly useful on the larger engines, which operate at slow speed, so that their governors have more time to move forward or backward under the influence of the force of gravity.

Hammering on the Stops

ONE very annoying difficulty with the single-arm shaft governor is its occasional tendency to hammer on the stops when shutting the engine down. This is caused either by the tendency of the governor arm to fall forward during half the revolution, which may carry it away from its stop as the engine turns very slowly before coming to rest; or by the jerky

action of the valve gear, which may coincide with the action of gravity and serve to pull the governor arm away from its stop at some point in the revolution. Little harm can be done by moderate hammering in this way, though cases have been known where governors which hammer excessively when shutting down, have broken off stops, requiring the replacement of stop pins by stronger ones. Generally, hammering on the stops can be reduced by adding weight on the spring side of the governor arm and increasing the tension of the spring correspondingly. Where an engine has this fault, a small weight on the spring side should be tried, and the spring tightened a little, and the effect then observed; if the hammering is decreased, a little more of the same treatment may remove it altogether or reduce it to a point where it will do no damage.

Friction is both useful and harmful to the action of the governor. In the early days of the Rites' governor, the governor arm pins were usually made very small to reduce friction at this point. The result sometimes was that the governors could not be held in their position, but would kick and hunt on the least provocation. Without intending to affect this condition, the governor pins were later designed much larger and heavier. The increased friction thus introduced had exactly the required effect to diminish irregular action and unnecessary movement of the governor arm due to trifling changes in conditions.

On the other hand, too much friction in governor pin, or brake, will oppose resistance to the proper movement of the governor arm, and may cause the engine to run alternately too fast and too slow. If the engine appears to have this defect, running along say 2 revolutions below normal, and maintaining this speed until the load has fallen considerably, then jumping to 2 revolutions above normal and maintaining the load at this point, the difficulty is probably due to stiffness in the governor action, and the pin or the brake should be examined accordingly.

Valve Friction

VALVE friction will cause the engine to speed up, and in fact screwing up the valve stem gland may have the same effect. One of the means employed by Mr. Rites to vary the speed of his governor through a small range as required in bringing alternating-current generators in parallel, has been to provide a dashpot, or a small friction of some kind, on the valve stem or valve gear, to add its effect to the tension of the spring and increase the speed of the engine.

Finally, in making adjustments on the Rites' governor, it is well to keep in mind the simplicity of the governor, and the corresponding simplicity of the means required for its adjustment. If therefore 3 or 4 changes have been made and the governor is still far from satisfactory, consider the changes and see whether they are of such a nature that they cancel one another. In adding weights, it is generally a change in the distribution of the weight on the governor arm, rather than an actual increase in the total weight of the arm, which is required. If a weight is to be added to one end of the governor arm, see first whether there is not a weight on the other end which may be taken off and produce the desired effect. If there is a weight on each end of the governor arm, perhaps one can be taken off instead of adding another to the opposite end. Care taken in advance of making changes, to study the effect to be produced and the various ways of producing it, will often save much time and several false moves in the process. If governor arms could be made of perfectly uniform cast iron, and machined to exact dimensions on every side, and if governor springs could be made with the accuracy of spring scales, governors would all act alike. It is surprising that variation in castings and in springs has after all so little effect on the Rites' governor that generally the addition of a little piece of cast iron is all that is required to overcome almost any difficulty.

ENGINE DETAILS

Types of Frames, Cylinders, Pistons, Crossheads and Connecting Rods

ENGINE FRAMES ARE DIVIDED into several types, the principal being tangye, girder, box, rolling mill, and angle frames. The tangye frame is one of the most familiar types and is largely used in Corliss engines and for heavy duty work, as the nature of its construction insures rigidity and strength. It is designed for an overhung crank and carries one main bearing, an outboard bearing being used to support the farther end of the shaft. Adjoining the cylinder it is of boxlike section in which the crosshead guides are cast or supported; openings are provided on the sides to afford access to the crosshead guides and piston rod stuffing box.

Reference to the illustration of the C. & G. Cooper heavy-duty Corliss engine and others will show that on the crank side the frame extends horizontally in line with the crank to support the main bearing, while the opposite side curves downward so that at the end it is but a few inches above the foundation. An area under the crank is lower than the outside edges and serves as a reservoir to catch the oil drippings.

Tangye frames are sometimes built in 2 pieces, that part which supports the crosshead guides being bolted to the main frame and to the cylinder; in some designs it is free from the foundation and in others it is supported by a base resting on the foundation as shown in the illustration of the Allis-Chalmers heavy duty Corliss engine.

The rolling mill type of frame is a modification of the tangye frame and is designed to meet the severe strains of the widely varying loads met with in rolling mill work. A rolling mill frame is shown in connection with the description of the Mesta Corliss engine.

In many manufacturing and other plants the steam pressures are moderate, for such plants the girder frame engine is suitable. The frame is of I section to which is cast the cylindrical housing for the crosshead and guides and as its name implies resembles a girder. It is generally supported at 2 points besides being bolted to the cylinder, under the crosshead and at the main bearing, this latter support being the pedestal for the bearing. The Nagle girder frame engine is an example of the type.

The box frame is an enclosed boxlike structure nearly to the shaft where it emerges into construction resembling a short tangye frame as shown in the Russell self-oiling engine. It is provided with openings at the side, which may or may not be covered, to afford access to the crosshead and stuffing box.

Vertical engine frames may be divided into 3 general classes, the A frame, marine type and angle frame. The first type derives its name from its resemblance to the shape of that letter as seen in the A. B. C. engine. The marine type has a cast-iron box column which inclines at an angle with the base and is braced by one or 2 wrought iron or steel rods, supported by the base and extending upward to the column at an opposite angle, as in the Bates high speed engine.

Engines with valves placed transversely in the cylinders, such as Corliss engines, necessarily use cylinders of box section at the ends.

Bearings

FOR large engines the quarter-box bearing is extensively used with lateral and vertical adjustment. The shells on each side of the shaft are adjustable and held in place either by wedges which can be raised or lowered by means of threaded bolts, as in the Rice and Sargent, or by set screws as in the Murray, thus adjusting the quarter boxes to the shaft with the greatest precision. By slightly raising the shaft, the bottom shell can be rotated and quickly removed.

A modification of the quarter-box bearing has but 3 parts, the bottom shell of the box is essentially the same as the quarter box but the side shells cover a greater area of the circumference of the shaft and come nearly together at the top as in Ideal engines. One of both of the side shells are adjustable.

Another modification consists of a shell divided into 3 parts with the bottom and one side in one piece and the opposite side an adjustable quarter box, as used on the Ames 4-valve engine.

Bearings with 2 part shells are usually arranged so that the division between the halves is in a line at a 45 deg. angle with the vertical, the upper part of the shell being adjustable as in the Ball single-valve engine. The common construction for bearings in small engines is the plain 2-part box with removable cap.

APPROXIMATE DIMENSIONS OF HIGH SPEED ENGINES, HORIZONTAL TYPE

Cylinder Size	H.P. at 100 lb. ¼ cut-off	r. p. m.	Flywheel			Piping		Shaft Journals		Crank Pin		Floor Space		Area of Port Opening		Total Wt. lb.
			Diam. in.	Face in.	Wt. lb.	Steam in.	Ex. in.	Diam. in.	Length in.	Diam. in.	Length in.	Length Ft. in.	Width Ft. in.	Steam sq. in.	Ex. sq. in.	
6x 6	20	450	33	6	500	2	2½	2¾	5	1½	1⅝	6–0	3–6	2¼	3¼	3000
6x 8	25	400	38	7	600	2	2½	2¾	5	1½	1⅝	6–4	4–0	2½	3½	3500
6x10	30	350	38	8	650	2	2½	2¾	5	1½	1⅝	6–6	4–0	2¾	4¼	3800
7x 8	30	400	40	7	650	2½	2½	3½	6	1¾	2	6–4	4–0	3½	5¼	3700
7x10	35	350	40	8	750	2½	3	3½	6	1¾	2	6–6	4–6	4	5½	3900
8x 8	40	400	40	8½	700	2½	3	4	7	2	2¼	6–4	4–0	4½	6¾	4000
8x10	45	350	42	9	750	2½	3	4	7	2	2¼	7–6	5–0	5	7½	5000
8x12	50	300	48	9	850	3	3	4	7	2	2¼	7–8	5–0	5	7½	5300
10x10	60	325	50	10	1200	3½	4	5	9	2½	2¾	8–0	5–0	7	11	5800
10x12	75	300	50	12	1400	3½	4	5	9	2½	2¾	8–6	5–4	7¾	11¾	7200
11x10	75	325	50	12	1400	4	4½	5½	10	2¾	3	8–0	5–4	8½	13½	6200
11x12	85	275	54	12	1600	4	4½	5½	10	2¾	3	9–6	5–4	8¾	13½	7600
12x10	85	325	54	12	1600	4	4½	5½	10	3	3½	8–0	5–4	11	15¾	6500
12x12	100	275	60	12	1800	4	5	5½	10	3	3½	9–0	5–4	11	15¾	8500
12x14	110	275	60	14	2000	4	5	5½	10	3	3½	9–6	5–6	12	18	10500
13x12	110	275	60	13	2000	4	5	6	10	3½	3¾	9–0	5–4	12	18½	9600
13x14	125	260	60	14	2250	4	5	6	10	3½	3¾	10–0	5–6	14	20	11000
14x12	130	275	60	14	2250	4½	5½	6½	12	3½	4	9–6	5–4	14	21½	10000
14x14	150	260	66	14	2500	5	6	6½	12	3½	4	11–0	6–6	15½	23	11600
15x14	175	260	66	16	2800	5	6	7	12	3¾	4½	11–0	6–6	17½	26½	12000
15x16	180	250	66	16	2800	6	7	7	12	3¾	4½	12–0	7–6	19½	29	14000
16x16	205	250	66	18	3000	6	7	7½	14	4	4½	12–0	7–6	22	33	15800
16x20	250	200	72	18	3500	6	7	7½	14	4	4½	14–0	7–6	22	33	20000
18x18	260	225	72	20	4000	7	8	8	16	4.½	5	14–0	9–0	28	43	20000
18x20	275	200	76	20	5000	7	8	8	16	4.½	5	14–6	9–0	28	43	25500
20x20	320	185	80	20	5500	8	9	9	18	5	6	14–6	10–0	32	48½	26500

In the angle compound arrangement, 2 engines, one horizontal and one vertical, connect to the same crankpin so that the inertia forces of each engine are made to neutralize those in the other. The American-Ball angle compound is an example of an engine of this form.

Cylinders

THERE are practically no distinctive types of cylinders, the principal difference being in some details of design and construction. Some engine makers build cylinders with the forward head cast solid with the cylinder, but the general practice is to have it as an integral part of the frame.

Another distinguishing characteristic of cylinders is the placing of the valves in the cylinder heads as exemplified in the McIntosh & Seymour type F engine described elsewhere in this issue. In some engines the cylinders are overhung from the frame, while others are supported by the bed plate. For most slide-valve or piston-valve engines the steam chest forms a part of the cylinder casting.

Crossheads

CROSSHEADS have 4 general divisions, locomotive type, box type, slipper type and H type. The locomotive type is one of the most familiar forms of construction for many types of horizontal engines using box beds. It consists of a hollow U-shaped

casting, the sides of the U being square in section, with the crosshead pin cast integral with it. The wearing surfaces are faced with babbitt or some anti-friction metal, and adjustment for wear is made in the guides.

Box type crossheads consist of a box-head casting open at one end and provided with adjustable shoes at the top and bottom. In some constructions the shoes are tapered and are adjusted by moving them forward or backward by means of bolts passing through the crosshead checks as in the Allis-Chalmers Corliss engines. Another form of construction employes a wedge between the shoe and crosshead, the adjustment being made by screwing the wedge backward or forward.

The slipper type of crosshead consists of a U-shaped casting attached to a slipper that travels between the crosshead guides; the crosshead pin is removable as in the box type. The single-valve center-crank engine manufactured by the Ames Iron Works employes a crosshead of this type.

The H-type crosshead consists of a hollow casting with the shoes bolted to each side as illustrated by the Ridgeway single valve engine. The lower shoe is made adjustable by means of screws passing through the body which force the shoe and body apart or allow them to come together. In some crossheads of the box types shims are employed for adjustment.

APPROXIMATE DIMENSIONS OF CORLISS HORIZONTAL ENGINES.

Size of Engine	Revolutions Per Minute	Piston Speed Feet Per Minute	Horsepower at 100 lb. Steam Pressure and ¼ cutoff.	Flywheel			Weight of Engine and Flywheel Complete	Pipe		Shaft Journal		Crank Pin		Floor Space		Steam Lap, In.	Steam Lead, In.	Exhaust Lap, In.	Trial Compression, In.
				Diam. Ft.	Face, In.	Weight Pounds		Steam, In.	Exhaust, In.	Diam. In.	Length, In.	Diam., In.	Length, In.	Length Ft.-In.	Width Ft.-In.				
10x24	120	480	61	8	13	5,000	12,270	3	4	5	10	3	3	15–4	6–4	¼	⅛	⅛	1½
11x24	120	480	74	8	13	7,000	14,600	3	4	5½	11	3	3	15–5	6–4½	¼	⅛	⅛	1⅝
12x30	90	450	83	9	13	10,000	21,100	3	5	6	12	3½	3½	18–6	6–10	⅜	⅛	⅛	2
14x32	90	479	114	10	15	10,800	26,500	3½	5	7	14	4	4	19–9	8–0	⅜	⅛	⅛	2¼
16x42	78	546	179	12	23	12,600	34,800	4	6	8	16	4	4	24–11	8–4	⅜	⅛	⅛	2¼
18x42	78	546	227	14	25	15,000	37,900	5	7	9	18	5	5	26–1	9–8	⅜	⅛	⅛	2½
20x42	75	525	270	16	31	18,000	48,300	5	7	10	20	5½	5½	27–4	10–5	⅜	⅛	⅛	2½
22x44	80	586	343	14	37	23,000	56,600	6	8	11	22	5½	5½	28–0	11–0	⅜	⅛	⅛	2½
24x48	70	560	414	16	40	27,000	81,300	7	10	12	24	6	6	30–0	11–9	⅜	⅛	⅛	2¾
26x52	75	649	530	16	40	30,000	92,000	7	10	13	26	6½	6½	30–8	12–6	⅜	⅛	⅛	2¾
28x48	68	544	548	18	40	34,000	95,000	8	10	14	28	7	7	31–3	13–4	⅜	⅛	⅛	2¾
28x56	70	522	620	18	40	37,500	94,500	8	10	14	28	7	7	32–0	13–7	⅜	⅛	⅛	3
30x48	68	544	629	20	40	38,000	140,000	8	10	15	30	7½	7½	32–8	13–11½	⅜	⅛	⅛	3¼
30x60	62	620	717	22	40	40,000	149,000	8	10	15	30	7½	7½	38–2	13–11½	⅜	⅛	⅛	3¼
32x56	70	653	814	22	40	44,000	.....	10	12	16	32	8	8	39–0	15–0	⅜	⅛	⅛	3¼
34x60	62	620	920	24	60	50,000	.....	10	12	17	34	8½	8½	39–6	16–4	⅜	⅛	⅛	3¼
36x72	55	660	1099	25	60	62,000	.....	12	14	18	36	9	9	44–6	16–4	½	⅛	⅛	4
40x72	55	660	1356	26	60	84,000	.....	14	16	20	40	.....	.....	.....	.....	⅝	⅛	¼	3½
42x60	62	620	1405	26	60	94,000	.....	14	16	21	42	.....	.....	.....	.....	⅝	⅛	¼	3¾
44x60	62	620	1542	28	.....	100,000	.....	16	18	22	44	.....	.....	.....	.....	⅝	⅛	⅛	3¾
46x72	55	660	1794	29	.....	106,000	.....	16	18	23	46	.....	.....	.....	.....	⅝	⅛	⅛	4¼
48x72	55	660	1954	30	.....	110,000	.....	16	18	24	48	.....	.....	.....	.....	⅝	⅛	⅛	4

Pistons

STEAM engine pistons may be divided into 4 general classes; solid, hollow, conical and built-up types, each type having many modifications peculiar to the designs of the manufacturer. For small engines with cylinders less than 10 in. in diameter the solid cast iron or steel piston is frequently used, the piston rod being inserted and secured by a nut. There are several methods in use for securing the piston rod; a common construction is to have the end of the rod that is inserted in the piston tapered, with or without a shoulder to bear against the side of the piston, and secured with a single nut, the end being riveted over. In other forms the rod is made a forced fit through the piston and projects sufficiently to receive a nut.

In the outside of the piston are one or more rectangular grooves to receive the packing rings. These rings are turned eccentric from cast iron and cut through in one place in such a manner that the ends lap; they are then sprung open enough to slip over the piston and slip into the grooves and retain their position by reason of the elasticity of the metal. A form of piston much used consists of a hollow casting provided with packing rings and otherwise similar in construction to the solid piston.

Conical piston with a conical casting with one or more packing rings is largely used in marine work and somewhat for stationary engines as illustrated in the American-Ball angle-compound engine. Its advantage is extreme rigidity for its weight and lightness, and in the angle frame it is desirable to have the vertical piston as nearly as possible the same weight as the horizontal piston to maintain balance.

Built-up pistons are largely used on large engines of the horizontal type to facilitate taking up wear which is greater with a heavy piston. The body is a spider with radiating arms, to which the follower plate is bolted. A bull ring is placed around the spider and is supported by studs and adjusting nuts, and in turn supports the packing rings which are usually of sectional form held out by coil or flat springs, as in the Allis-Chalmers and Rice and Sargent engines.

Connecting Rods

THERE are 3 general types of connecting rods, the strap, solid end and marine, each of which has its advantages for various classes of engines. The strap end type consists of a rod forging of iron or steel with a forged strap generally attached to the rod by 2 bolts with lock nuts. The brasses are flanged on both sides and slip into the strap. Numerous styles of adjustment for the brasses are in use, one consists of a taper key fixed by a set screw.

Liners are placed between the brasses and between the inner brass and the rod. As the brasses wear, liners are removed from between them and the wear taken up; the distance between crank-pin and crosshead pin centers can be regulated by adding or removing liners from the space between the brass and end of rod. This type of rod end is especially adapted to engines whose construction does not permit of the

rod being removed sidewise or with a box type of crosshead in which the crosshead pin is part of the head itself.

The solid end rod has the ends forged with the rod and the recess for the brass is cut out by drilling holes around its outline, then finishing on a shaper. The brasses are flanged on one side only, slip into the head, and are adjusted by wedges and bolts.

In the marine type rod, the rod is enlarged at the end to carry one half of the box and the other half is carried by a separate piece which is bolted on. Adjustment for wear is made by liners between the halves, and for length by liners between the inside half of the box and the rod.

Any connecting rod may have a combination of these types, for example, a marine end and a solid end.

A special form is seen in the Harris Corliss engine, where one side of the end is removable and held in place by a bolt, to allow of taking off the rod readily.

Flywheels, Shafts and Cranks

FLYWHEELS are used to steady the speed against fluctuations, and equalize the varying turning effort on the shaft by storing energy during the first part of the stroke, where the crank effort is greater than the resistance, and restoring it when the steam pressure decreases with expansion. On small engines they are generally cast in one piece and pressed onto the shaft by hydraulic pressure. To relieve stresses, moderate sized flywheels of heavy section are usually provided with a split hub through which heavy bolts pass for clamping the wheel securely to the shaft. For diameters too large for convenient handling or shipment, wheels are made in halves with bolts for the hub, the rim being held together by links set into recesses in the rim, or by bolts, or both. With this construction one half of the wheel can be lowered into the wheel pit, when erecting the engine, before the shaft is placed, when the upper half can be assembled on the shaft.

For very large engines the weight of the wheel necessitates making it in segments, the sections of the rim being united in a manner similar to that of a 2-part wheel while at the hub, ends of spokes are bolted between sections of a hub made up of 2 disks pressed on the shaft.

Shafts are made in numerous forms the principal types being the solid forged, the solid forged center crank and the built-up shafts. The solid forged center-crank shaft as used in the Sturtevant vertical engine is forged with a projection on one side near the center and cut out, leaving a blank for the crank-pin which is turned by placing the shaft in the lathe in such a position that the axis of the crank-pin is in line with the lathe centers. Such a shaft is generally balanced by bolted on weights.

Built-up shafts are frequently employed in center-crank engines, the shaft being made in 2 pieces which are pressed into disks; disks are connected by the crank-pin forming the crank.

Fleming Harrisburg engines use a disk crank with the pin cast solid. A common construction is a disk crank with the pin pressed into it. Disk cranks are balanced by making them heaviest on the side opposite the crank pin while the plain crank is frequently balanced by weights bolted on and are known as fantail cranks.

SUPERHEATED STEAM

Why It Saves Steam and How Much. Practical Difficulties in Using It, How to Avoid Them and the Limit of Superheating for Economy

TO appreciate fully the value and effects of superheating steam, a short description of the Rankine cycle or diagram will be helpful. This cycle gives the most efficient possible performance by steam without evaporating and condensing the working fluid within the engine cylinder, and has, therefore, been adopted as the standard of efficiency with which all other cycles may be compared. Figure 1 shows the indicator diagram of this cycle and it may be noted that the engine is assumed to have no clearance and the walls of the cylinders to be nonconductors of heat.

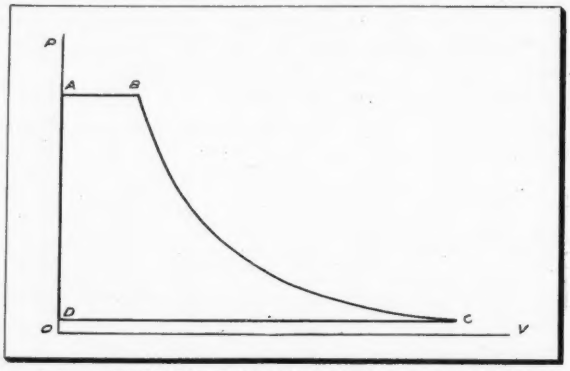


FIG. 1. INDICATOR DIAGRAM OF THE RANKINE CYCLE

After cutoff, the steam expands adiabatically to the pressure of the exhaust pipe. Exhaust takes place against constant back pressure and at constant temperature. There is no compression curve and the admission line is vertical.

The efficiency of this perfect cycle is equal to the difference between the total heat of the steam admitted and the amount of heat in the wet steam discharged, divided by the difference between the total heat of the steam admitted and the heat of the liquid at the temperature of exhaust.

It may be shown that increasing the temperature range of the working fluid increases the efficiency of the cycle, also that increasing the quality of the working fluid increases the efficiency of the cycle. To increase the temperature of saturated steam, without superheating, it is necessary to increase the pressure but the quality of steam may be increased and the steam superheated without increasing the pressure. The relation between efficiency of the Rankine cycle and quality and superheat is shown for steam pressures of 100 and 175 lb. in Fig. 2 which has been plotted by Professor Cardullo.

It will be seen from this that the efficiency of the cycle is increased about 1 per cent by superheating 200 deg. F. This gain is for equal volumes of steam; there is also a saving in steam due to increase of volume by superheating.

There is another quality of steam which would indicate a small advantage in the use of superheated steam and that is the effect of latent heat to reduce the power available in steam. About 4/5 of the heat used in making steam is absorbed as latent heat, and, since it cannot be turned into mechanical power, is as far as the engine is concerned.

The percentage of this loss can be decreased by superheating.

Experts of the Russian State Railways give the following results as the saving due to superheating steam:

Superheat, deg. F.....	68	104	140	176	212	302
Coal saved, per cent..	5	9	12	14.5	17	24
Steam saved, per cent.	8	12.5	16	20.5	24	34

According to Stirling, the amount of fuel required to superheat steam, and the quantity of fuel that must be burned to produce this heat, are greater than is commonly supposed. The specific heat, according to best authorities, varies at atmospheric pressure, from 0.48 at saturation, to 0.65 at 100 deg., and 0.75 at 200 deg. superheat. Using these values, it can be calculated that the fuel used to generate saturated steam must be increased by about the following percentages in order to superheat the steam to the degrees named:

Deg. of Superheat.....	75	100	150	200	250
Additn'l fuel needed, per cent	5	7	11	15	20

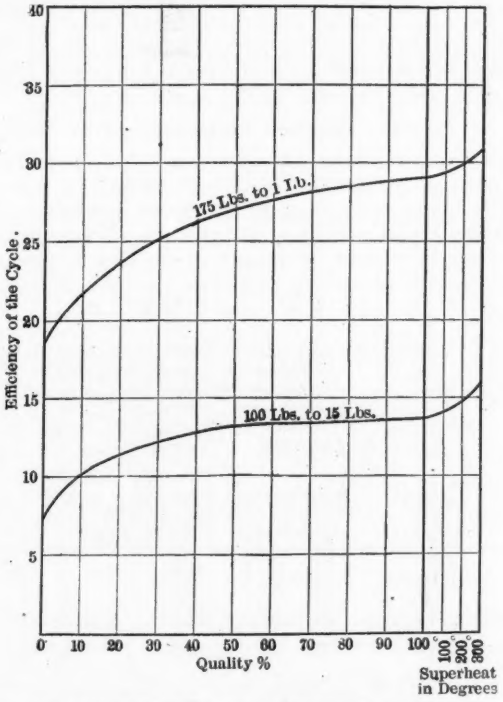


FIG. 2. RELATION BETWEEN THE EFFICIENCY OF THE RANKINE CYCLE AND THE QUALITY AND SUPERHEAT OF STEAM

Professor R. H. Thurston, however, arived at the following conclusions in regard to the use of superheated steam in reciprocating engines: That as hitherto employed it has no value in raising possible efficiency; that its sole purpose is the reduction of the internal wastes of the engine, from initial or cylinder condensation; and is the best known means of reducing that waste; that no trouble need be found at the engine with sufficient superheating under usual conditions of operation, to annihilate cylinder condensation; that the more wasteful the engine, the larger the promise of gain by superheating, and the farther should the superheating be carried. Small engines will profit by it more than large, slow engines more than fast, and single engines more than multiple-cylinder systems.

From the above it would appear that the only good reason for using superheated steam is to eliminate initial condensation, which amounts to seldom less than 20 to 30 per cent of the saturated steam used, and when this has been accomplished, there is no economy in superheating further.

Condensation in the pipe line may also be eliminated by superheating, and the pipe size may be made smaller for a given quantity of steam as friction is less and velocities may be higher.

Practical difficulties, however, have been met and it is only in recent years that these have been overcome sufficiently to make the use of highly superheated steam for engines commercially successful.

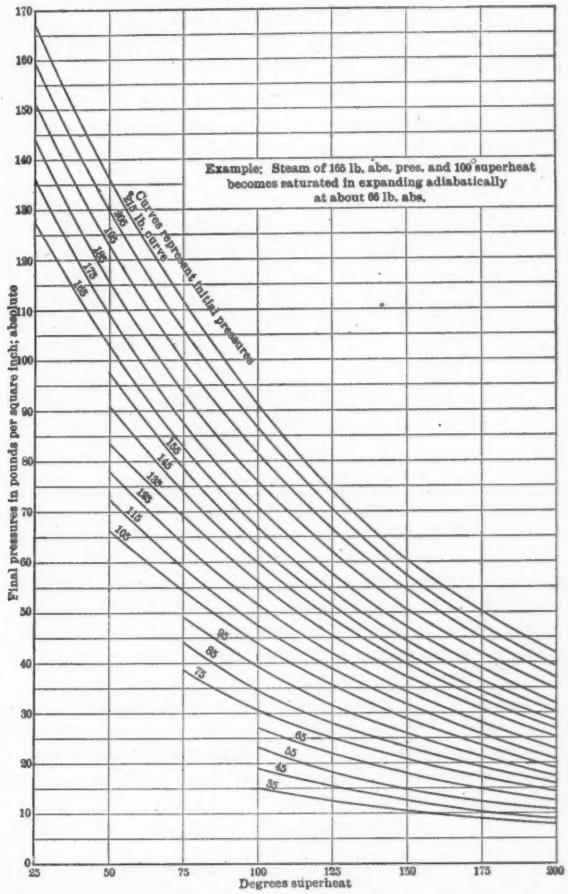

Example: Steam of 165 lb. abs. pres. and 100° superheat becomes saturated in expanding adiabatically at about 66 lb. abs.
Curves represent initial pressures
Final pressures in pounds per square inch; absolute
Degrees superheat

FIG. 3. CHART SHOWING PRESSURES AT WHICH SUPERHEATED STEAM BECOMES SATURATED DURING ADIABATIC EXPANSION

Principal among the difficulties are to get suitable steam valves, lubrication, rod packing and gasket material. Valve troubles have now been overcome by the use, almost exclusively, of poppet valves which require no lubrication and are not materially affected by expansion strains. The labyrinth packing is used for the rods, thus doing away with material that will deteriorate with high temperatures. For flange joints, either ground joints or metallic gaskets are available for use on engines and pipe lines using superheated steam.

AT THE FINAL session of the National Gas Engine Association, the city of Springfield, Ohio, was chosen as the meeting place for the next convention in December, 1913.

THE STEAM TURBINE

Impulse and Reaction Types, Single and Double Flow, Low Pressure and Bleeder Arrangement

STEAM TURBINES OPERATE BY abstracting the velocity energy of steam jets through their action on curved blades in the same way as in water turbines. The differences in design are due to the high velocity and small weight of the steam jet as compared to the water jet. A jet blown from a pipe against a series of flat paddles on the rim of a wheel is the simplest form, but has very low efficiency. To get the best results, the jet must be formed in a nozzle

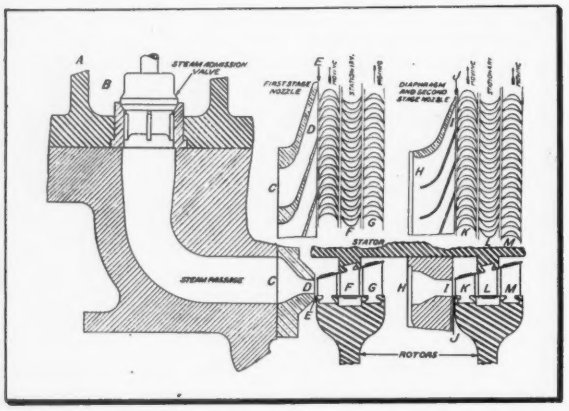


FIG. 1. CURTIS TYPE OF IMPULSE NOZZLES AND BLADES FOR 2 STAGES

that has a shape to give the highest velocity; and the wheel blades must be of such shape and arranged to run at such speed as to abstract the largest possible amount of the velocity energy of the jet before leaving contact with it.

Primarily, steam turbines are divided into 2 general classes, those employing the impulse principle and those employing the reaction principle, although in later machines these types have been combined in one turbine with excellent results.

Impulse Type

IN turbines of the impulse type complete expansion for any one stage takes place in the nozzles, and the steam is delivered to the moving blades with a velocity somewhat more than double that of the blades. Pressure throughout a stage is practically constant, the passages between the moving blades being of uniform or even slightly increasing cross-section from inlet to outlet. The moving blades check and reverse the motion of the steam current and the resistance of the steam current to this change exerts a force against the blades which sets the rotor in motion.

If it were possible for the direction of the jet to be completely reversed, or through an arc of 180 deg., and the velocity of the blade in the direction of the entering jet was one-half the velocity of the jet, then all the kinetic energy due to the velocity of the jet would be converted into work on the blade and the final velocity of the jet with reference to the earth would be zero. This complete reversal, however, is impossible, since room has to be allowed between the blades for the passage of the steam, and they are, therefore, curved through an arc considerably less than 180 deg. so that the jet on leaving the wheel still has some kinetic energy.

The impulse type of turbine works with high steam velocities and few stages. Each stage may, however, be provided with 2 or more rows of revolving blades, known as velocity rows, with intermediate rows of stationary guide blades, which reduce velocity and take out energy until the steam reaches a diaphragm, which extends to the shaft and which carries the orifices between stages, when it expands through these orifices, losing pressure and again gaining a high velocity. Figure 1 is a diagram showing the arrangement of nozzles and buckets in a 2-stage Curtis turbine.

Characteristics of the impulse or velocity type of turbine may be classified as follows: Few stages; expansion takes place in nozzles; large drop in pressure per stage; initial steam velocities 1000 to 4000 ft. a second; blade velocities 400 to 1200 ft. a second; best efficiency is obtained when the blade velocity is nearly half the initial velocity of the steam.

Reaction Turbines

IN the reaction turbine, approximately one-half the expansion in any one stage takes place in the stationary blades, imparting to the steam a velocity substantially equal to that of the moving blades, so that

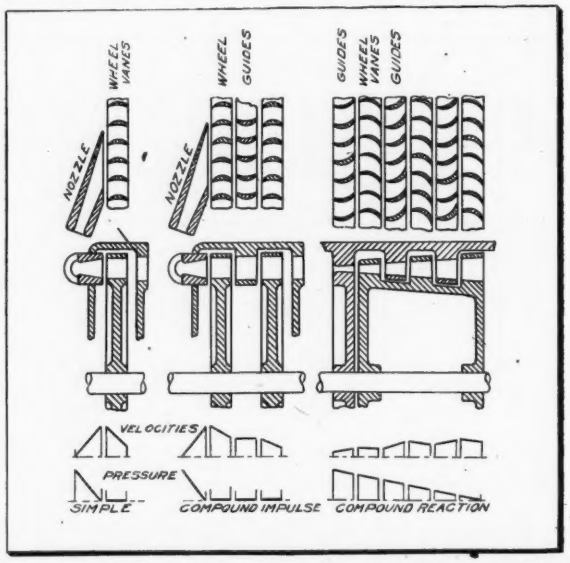


FIG. 2. NOZZLES, GUIDES AND WHEEL BLADES OF IMPULSE AND REACTION TYPE TURBINES. 1, SIMPLE, IMPULSE; 2, COMPOUND SINGLE STAGE IMPULSE; 3, COMPOUND REACTION.

it enters them without impact. The remainder of the expansion takes place in the moving blades, the spaces between which gradually grow larger from the inlet to the exit side of the turbine, forming a ring of moving nozzles. The velocity imparted to the steam by reason of the expansion occurring in the moving blades, produces a reactive effort on these blades which turns the rotor of the turbine. This effect is similar to that produced by water issuing from an ordinary hose nozzle. The arrangement of Fig. 3 is an example of the reaction turbine.

Some of the characteristics of the reaction type of turbine are: Many stages; no nozzles; small drop in pressure in a stage; steam velocities low, 300 to 600 ft. a second; blade velocities 150 to 400 ft. a second; the best efficiency is obtained when the blade velocity is nearly equal to the highest steam velocity.

Each of these 2 general classes of turbines has its partisans, and doubtless always will have, but in later practice combination of the 2 principles is utilized to gain the advantages of both.

The use of a single-impulse element for the first stage of the expansion is desirable, inasmuch as it replaces without any appreciable sacrifice of economy, a considerable number of rows of reaction blading in the least efficient part of a reaction turbine, and makes possible a shorter and consequently stiffer rotor.

The all-impulse type necessitates a rotor built up of disks mounted on a shaft of small diameter, in order that the clearance between the shaft and the diaphragms separating the pressure chambers may be as small as possible, so that the considerable pressure drops between adjacent stages will not cause too much leakage.

In the reaction type, the pressure drops between adjacent stages are much smaller, and the body of the rotor may be built up in the form of a hollow drum, which is much stiffer than the shaft and disk design.

Variations in Design

DEVELOPMENT of high-speed alternating-current generators of large capacities has made it desirable to make certain radical departures from the conventional reaction design. Three modifications are shown diagrammatically in Figs. 1, 3, 4 and 5.

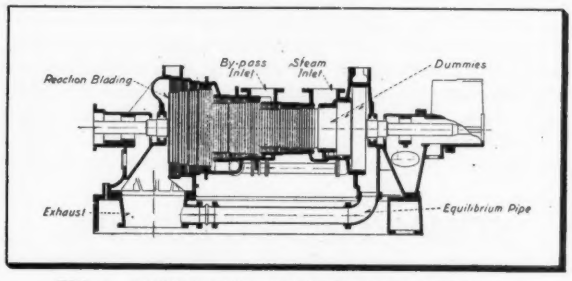


FIG. 3. SINGLE FLOW REACTION TYPE TURBINE

Single-Flow Type

FIGURE 3 illustrates the original single-flow reaction type. Steam is admitted to an annular chamber in the casing, from which it passes alternately through rings of fixed and moving blades on the small diameter of the drum or rotor; the blades are of progressively increasing lengths, so that the steam expands in volume as it passes through the successive rings, and when the volume of the steam has increased so that blades on this small diameter of drum to provide passageway for it at reasonable velocity, would be inconveniently long, the diameters of drum and casing are increased for the next stage of the expansion. The available area of the steam passage through the blades is a fairly constant percentage of the product of the mean circumference of the blade ring multiplied by the height of the blades.

If the mean diameter of the ring of blades in the second stage be increased to about 1.42 times that in the first stage, the area through each blade ring per inch of blade height will be 1.42 times that through the first stage rings. On account of the larger diameter, the mean speed of the blades will also be 1.42 times that the blades in the first stage, consequently the actual velocity of the steam through the blades in the second stage may be 1.42 times that in the first stage, yet have the same velocity relative to the blades. If the area through the second stage blades per inch of height and the velocity of the steam through the blades are both 1.42 times as great as in the first stage, then to pass the same volume of steam per second the blades in the second stage need be only one-half as high as those in the first stage.

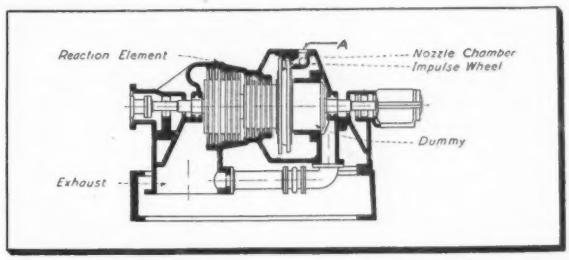


FIG. 4. COMBINED IMPULSE AND REACTION ARRANGEMENT

As the steam expands in the second stage, its volume will increase until the blade heights required again become excessive. The drum diameter is again increased, and the blades heights on the enlarged diameter are reduced. Expansion proceeds in other stages through progressively increasing blade rings until the pressure of the steam falls to that of the exhaust.

Impulse and Reaction Single-Flow Type

A MODIFICATION of the single-flow design is illustrated in Fig. 4 in which the smallest barrel of reaction blading is replaced by an impulse wheel. Steam is admitted to the nozzle block A, is expanded in the nozzles and discharged against a portion of the blades on the impulse wheel. The intermediate and low-pressure stages are indentical with the corresponding stages in the reaction type illustrated in Fig. 3. The substitution of the impulse element for the high-pressure section of reaction blading has no influence one way or another on the efficiency. That is to say the efficiency of an impulse wheel is about the same as the least efficient section of reaction blading. This design is attractive, however, in that it shortens the machine materially, and gives a stiffer design of rotor.

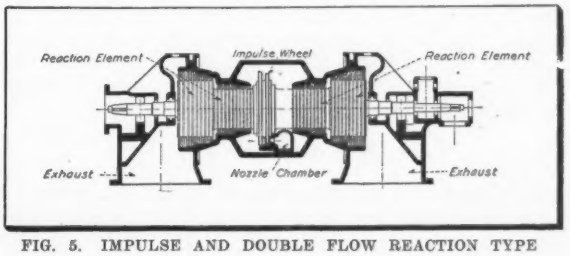


FIG. 5. IMPULSE AND DOUBLE FLOW REACTION TYPE

Entering steam from the nozzle chamber has its pressure and temperature materially reduced by expanding through the nozzles. As the nozzle chamber is cast separately from the main cylinder, the temperature and pressure differences to which the cylinder is subjected are correspondingly lessened. The straight reaction type has, however, probably on account of its small diameter at the high-pressure section, always shown itself to be adequate for all steam

pressures and temperatures encountered in ordinary practice. The principal advantage of the high-pressure impulse element, is that without any sacrifice of economy, it shortens the rotor to such an extent as to make a double-flow design practicable.

Double-Flow Turbine

MAXIMUM economical capacity of a single-flow turbine is limited by the rotative speed as the economical velocity at which steam may pass through the blades of the turbine depends on the velocity of the moving blades. The capacity of the turbine depends on the weight of the steam passed per minute, which in turn depends on the mean velocity of the blades and their height. For a given rotative speed, the mean diameter of blade ring practicable is limited by the allowable stresses due to centrifugal force, and there is a practical limit for the height of the blades.

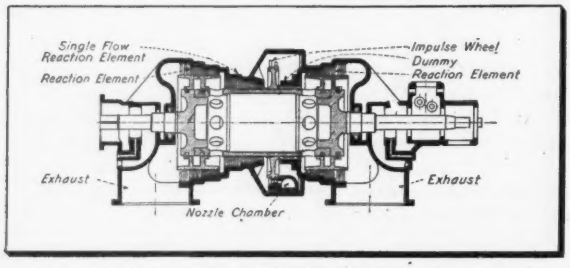


FIG. 6. IMPULSE HIGH PRESSURE STAGE, SINGLE FLOW SECOND ELEMENT AND DOUBLE FLOW IN THIRD ELEMENT

Now if we make the rotative speed only half as great, the maximum diameter of the rotor may be doubled and, without increasing the height of the blades, the capacity of the turbine will be doubled. So with the single-flow steam turbine, as with the single-crank reciprocating engine, there is a practical limiting economical capacity for any given speed. If this limit is reached with a single-crank reciprocating engine, we may produce a unit of double the power at the same speed by coupling 2 single-crank engines to one shaft. We accomplish similar results by making a double-flow turbine which is in effect, as will be seen from Fig. 5, 2 single-flow turbines made up in a single rotor in a single casing with a common inlet and 2 exhausts. Steam enters through the nozzle chamber, acts on the impulse element, and then the current divides, one-half of the steam going through the reaction blading at the left of the impulse wheel; the remainder passes over the top of the impulse wheel and through the impulse blading at the right.

Semidouble-Flow Type

FIGURE 6 is a modification in which the intermediate section of reaction blading is single-flow, and the low-pressure section only is double-flow. This would be analogous to a triple-expansion reciprocating engine with one high-pressure, one intermediate pressure and 2 low-pressure cylinders, a design not at all uncommon in very large engines in which the required dimensions of a single low-pressure cylinder would be prohibitive. Such turbines are useful for capacities greater than is desirable for a single-flow turbine, and which are still below the maximum possibilities of a double-flow turbine of the same speed. In such machines the best efficiency is secured by making the intermediate blading in a single section large enough to pass the entire quantity of steam.

A dummy similar to those used on the single-flow reaction type, shown at the right of the impulse wheel, compels all of the steam to pass through the single intermediate section; the current is then divided, one-half passing directly to the adjacent low-pressure section, while the other half passes through the holes shown in the periphery of the hollow rotor and through the rotor itself, beyond the dummy ring, into the other low-pressure section at the right-hand end of the turbine.

There are sound engineering reasons for the existence of single-flow, double-flow, and semidouble-flow turbines. The double-flow turbine is not a design that is inherently superior to the single-flow design, but it is used under conditions for which the single-flow machine is unsuitable. Similarly, the semidouble-flow is recommended only for conditions which it can meet more satisfactorily than either of the other types.

Special Turbines

TWO special adaptations are the low-pressure or exhaust turbine, and the bleeder turbine. Low-pressure turbines use exhaust steam from other apparatus and are valuable as expanding to lower pressures than could be utilized by reciprocating engines and for the purpose of increasing economy and capacity with a minimum outlay for new equipment.

Bleeder turbines are for use in plants which are required to furnish, not only power, but also considerable and varying quantities of low-pressure steam for heating purposes. In these turbines a part of the steam after it has done work in the high-pressure stages may be diverted for heating or industrial use, and the remainder expanded through the low-pressure blading and exhausted into the condenser. In this way, none of the energy of the heating steam, due to the difference of pressure between the boiler and the heating system, is wasted. On the other hand, if no steam is required for heating purposes, the turbine operates just as efficiently as if the bleeder feature were absent.

STEAM TURBINE DETAILS

Governing and Governors, Blades, Wheels, Diaphragms and Bearings

FOR governing the speed of turbines there are 3 general types of governors in use: The balanced throttling valve, multiple closing or relay valves, and intermittent admission. Turbines of standard make are examples of these 3 classes. Another method of governing is used in connection with the intermittent admission which consists of a means for admitting high-pressure steam directly to the later stages of a turbine by means of a bypass valve in order to provide for heavy overloaded conditions.

The speed of Parsons turbines is usually controlled by a centrifugal governor of the Hartung or similar type which regulates the piston of a balanced poppet valve through the medium of a steam or oil relay. The latter type is coming into more general use on account of its many advantages over the steam relay. The steam is throttled either at constant pressure or by a pulsating action.

Impulse turbines, and turbines employing a high-pressure nozzle ring usually govern by means of Hartung type governors and oil relays. The speed is sometimes controlled by simple throttling of the steam, as with the De Laval turbines; additional nozzles can be opened or closed by hand as required; but this

system would be unsuitable with violently fluctuating loads. Other types employ both throttling and automatic nozzle regulation, while, again, many turbines, particularly of the Curtis type, are built for nozzle governing alone.

The Westinghouse Machine Co. uses a vibrating oil relay system on many of its machines. Recently it has adopted on some sizes a powerful governor which is direct-connected to the governing valve and operates it without the use of relays.

All turbines are now provided with a small overspeed governor, usually placed at the outside end of the shaft. This operates at a determined percentage overspeed and closes the main or secondary steam valve either by means of a steam or oil relay or by a falling weight through a system of levers and springs. The oil relay system has the advantage that the valve shuts immediately should the oil supply fail for any reason.

Reaction turbines are usually provided with a secondary overload valve and bypass which automatically admits live steam to the second diameter of blades. Impulse turbines have additional sets of nozzles with valves which may be opened automatically, or by hand in case of overloads.

On the larger sizes of Curtis turbines a governor of the multiple or relay control type is used, with which the speed is controlled by opening and closing small valves admitting steam to the separate nozzle sections. These valves are operated from the governor mechanism and are designed to be fully opened or shut, like a pop safety valve, in order to prevent cutting of the seats by wire drawing.

Control of the nozzle valves by the governor has been effected by means of positive mechanical connections, electrical connections, and hydraulic cylinders. The last method has been found most satis-

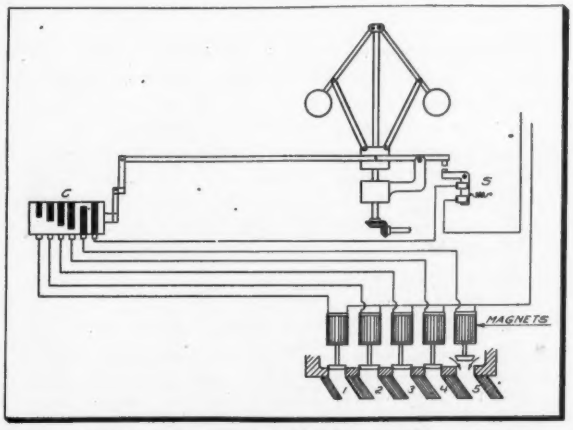


FIG. 1. DETAILS OF CURTIS GOVERNOR WITH ELECTRICALLY OPERATED VALVES

factory and is used on the later machines. Control by multiple valves gives excellent economy, as the steam is used at an almost constant thermo-dynamic efficiency, whatever the load.

The electrical method of control by multiple valves is shown diagrammatically in Fig. 1. In actual practice, however, the electro-magnets operate pilot valves which in turn control the admission valves. The governor actuates an electric controller which connects the various electro-magnets, to the source of current, the number connected depending upon the load. A safety switch is tripped when a predetermined speed is reached which disconnects the controller and magnets from the source of current supply.

Nozzles

HIGH-PRESSURE nozzles in impulse or combination turbines are made of bronze or nickel steel highly polished inside and placed either in the upper end of the casing itself, or, preferably, in a separate steel casting which bolts upon the casing. In the latter construction the casing itself is never subjected to the high temperature or pressure of the entering steam.

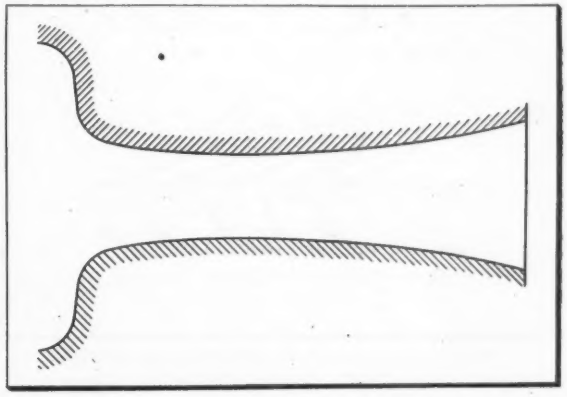


FIG. 2. SECTION OF DIVERGENT NOZZLE

Nozzles in the diaphragms between stages are usually made of nickel steel or other special steel, bent to the proper form and cast in place in the diaphragm body. Some manufacturers use brass nozzles in place of steel, made up in sections and riveted or bolted in place.

All these passages must be smooth and preferably very highly polished to reduce friction losses. In practice frictionless flow of steam through a nozzle is not possible as there is always some friction between the steam and the nozzle walls and this causes a reduction of the final velocity of the steam.

The friction of the steam in the nozzle generates heat, most of which is returned to the steam, improving its quality, hence the friction work is not entirely lost. From experiments that have been made, it is reasonably safe to assume a friction loss of 10 per cent, of the total heat drop as an average value for nozzles.

When expanding nozzles, shown in Fig. 2, are used the pressure at the throat cannot be less than 0.58 of the initial pressure, but having passed this point there is nothing to preclude further expansion down to the pressure of the surrounding medium. The further expansion increases the velocity of the steam, but unless the flow is concentrated in one direction, the energy will be dissipated, and lost, for any useful purpose.

The function of the divergent nozzle used in turbine design is to direct the jet issuing from the throat in a definite direction so that the kinetic energy generated may be made available. There is no more energy in the flow from an expanding nozzle than from a simple orifice, but if properly proportioned the nozzle allows the steam to expand from the critical pressure

with a minimum of vibration, and renders the kinetic energy of the jet available along some definite line of action.

For short nozzles, whether rounded at the entrance, convergent or straight, there is a sudden drop of pressure just beyond the throat or entrance, to a pressure below that of the discharge chamber. The pressure returns to the pressure of the exhaust medium in a series of oscillations roughly proportionate to the depression, and decreasing as a damped vibration until at perhaps 1 or 1½ times the length of the nozzle the pressure has settled down to that of the lower medium. It is the function of a well designed divergent nozzle to reduce these oscillations to a minimum.

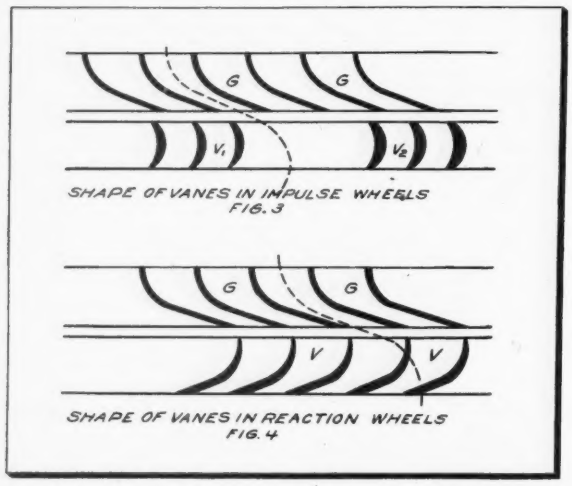


FIG. 3. SHAPE OF VANES IN IMPULSE WHEELS
FIG. 4. SHAPE OF VANES IN REACTION WHEELS

Blading of Reaction Turbines

IN Parsons turbines the blades are generally cut, punched or pressed into proper form from strips of drawn material. Some builders of turbines of the Parsons type use Sankey's solid foundation ring held in place by a soft metal calking strip. As this form is usually all machine made, it is considered by many engineers to be safer than where dependence is placed on hand work, such as must ordinarily be done where each distance piece is calked separately.

There are many methods in vogue for spacing and reinforcing the ends of Parsons blading. The Westinghouse Machine Co. uses a comma-shaped wire threaded through the blades near their outer end and bent over between them.

Blading of Impulse Turbines

IMPULSE blades are stamped from sheets, drop forged or milled from solid bars with or without a wide base to act as a distance piece, or are made from extruded metal strips of the desired cross-section. Usually these blades are of crescent section, but some are formed of flat material and made of constant thickness over the width of the blade. The separate distance pieces are usually of the same material as the blades themselves.

In general, all impulse blades are provided with shrouds to prevent vibration and also to provide an enclosed passageway for the steam at high velocities. As there is no drop in pressure between the 2 sides of a row of moving blades, the clearance can be made large, both on the end and sides, so that there is little possibility of rubbing when in operation.

Impulse blading is usually held in place in dovetailed grooves or in inverted T-shaped slots, although some manufacturers form their blades with 2 legs which straddle the disks and are held firmly in place by rivets.

Nearly all builders use blading on which the discharge side of the blade makes a sharper angle with the axis than the inlet side. This does not necessarily mean that the discharge area of the blades is smaller than the inlet area, for the blade is usually lengthened radially on the discharge side, so that inlet and discharge areas are made equal. The sharper angle of discharge reduces slightly the velocity of exhaust relative to the moving blade.

On turbines of the impulse type there is usually but a small difference between the inlet and outlet angles of the first row of moving blades, but on the second row of moving blades in the stage, the entrance and exit angles often differ by as much as 15 deg.

Some impulse turbine designs are such that there must evidently be some such effect in the moving blades as is obtained in reaction turbines, though not sufficient to cause any noticeable end thrust.

Shape of Vanes

IN Figs. 3 and 4 are shown the shape of moving vanes and guide vanes of impulse and reaction turbines respectively. In impulse turbines the wheel vanes are symmetrical or nearly so. In Fig. 3 G G are the guide vanes, which if the fall of pressure is small, need not provide diverging passages. The wheel vanes at V_1 have both faces parallel, and the vanes at V_2 are thicker at center than at the edges to maintain a constant area and so avoid possible eddy currents. The guide vanes in Fig. 4 are shown at G G and the wheel vanes at VV. This figure shows in a general way the contour that must be obtained in reaction turbines.

DIMENSIONS AND WEIGHT OF PORSONS TYPE TURBINES

Kw.	R. P. M.	Length.	Width.	Height.	Weight, lb.
	60 cycles 2	*or 3 phase.*	*Not over*	*6600 volts.*	
300	3,600	23 ft. 4 in.	4 ft. 0 in.	5 ft. 1 in.	36,500
500	3,600	24 ft. 6 in.	4 ft. 0 in.	5 ft. 1 in.	40,000
750	1,800	27 ft. 0 in.	5 ft. 10 in.	5 ft. 9 in.	65,200
1,000	1,800	29 ft. 0 in.	6 ft. 10 in.	6 ft. 6 in.	81,500
1,500	1,800	31 ft. 10 in.	6 ft. 10 in.	6 ft. 6 in.	103,000
2,000	1,200	34 ft. 9 in.	9 ft. 2 in.	8 ft. 2 in.	138,000
3,500	900	35 ft. 9 in.	10 ft. 6 in.	9 ft. 4 in.	237,000
5,500	720	46 ft. 0 in.	11 ft. 4 in.	10 ft. 6 in.	417,000
	25 cycles 2	*or 3 phase.*	*Not over*	*6600 volts.*	
300	1,500	23 ft. 6 in.	6 ft. 4 in.	5 ft. 9 in.	51,000
500	1,500	24 ft. 6 in.	6 ft. 4 in.	5 ft. 9 in.	56,600
750	1,500	28 ft. 3 in.	6 ft. 4 in.	6 ft. 0 in.	75,500
1,000	1,500	29 ft. 9 in.	7 ft. 6 in.	6 ft. 9 in.	104,200
1,500	1,500	32 ft. 6 in.	7 ft. 6 in.	7 ft. 0 in.	131,000
2,000	1,500	38 ft. 0 in.	9 ft. 0 in.	8 ft. 0 in.	166,000
3,500	750	42 ft. 5 in.	11 ft. 8 in.	10 ft. 5 in.	356,000
5,500	750	46 ft. 10 in.	13 ft. 2 in.	11 ft. 6 in.	460,000
7,500	750	50 ft. 10 in.	13 ft. 3 in.	11 ft. 6 in.	511,000

Bearings and Lubrication

PRACTICE varies widely with regard to the design and construction of journals and bearings. Builders of impulse turbines invariably use cast-iron bearing shells provided with spherical self-alining pads and lined with white metal. These are being used to

an increasing extent on Parsons turbines and without exception on all low-speed units. Some manufacturers still retain the original Parsons form of bronze bearing shell with concentric rings on the outside, separated from each other by oil films.

It has been claimed for this type of bearing that the oil films dampen any slight vibration of the spindle and thus provide a quieter running machine.

Practice seems to be tending towards flooded lubrication, in which a great quantity of oil at a temperature of about 100 deg. F. is forced through the bearings by a pump of the rotary, centrifugal or geared type, driven from the main shaft of the turbine. The oil pressure at the bearings varies from 3 to 20 lb. per sq. in. The life of the oil is much longer in this system than with very hot oil and wear on the bearings themselves is minimized.

Spindle Construction

PARSONS turbines in America are usually built with a hollow quill into which the journal ends are forced and fastened by shrink links or bolts. The high-pressure blading is placed in grooves in one end of the quill itself. The intermediate and low pressure blades are usually carried on cast or forged-steel rings which are afterwards forced and keyed upon the central quill.

Shafts of impulse turbines are usually in one piece and carry the blade disks, which are high-grade steel or nickel-steel forgings or castings. These disks are fitted and keyed on the shaft and held in place by shrink links or lock nuts. It is quite general practice now to design the shafts so that the normal speed of the turbine will be considerably below the critical speed due to any slight unbalancing of the mass that may be present.

Packing Glands

VARIOUS metallic and fibrous packings which give excellent results both as to wear and tightness in a stuffing box for a reciprocating piston rod, are not satisfactory when applied to a stuffing box on a shaft rotating several thousand times a minute. In general the packing in a steam turbine is subject only to a moderate pressure difference, that is, the difference between the pressure of the atmosphere and the vacuum at the exhaust end of the turbine. Instead of preventing the escape of steam from the turbine, the office of the packing is to prevent air leaking into it.

A small impeller supplied with water is provided on all American built Parsons turbines to form an air seal at the shaft glands.

Impulse turbines use carbon rings at the high-pressure gland, especially when superheated steam is used. The leakage past the first rings is carried through a passage and pipe to the low-pressure glands to act as a vacuum seal. The labyrinth packing in the diaphragms is usually of bronze in the high-pressure stages and frequently of white metal in the low-pressure section. The low-pressure shaft glands are made either with carbon or labyrinth packing, sealed by steam.

Thrust Bearings

THRUST bearings are now provided on all types of turbines. These serve to adjust the position of the spindle and to take up any end thrust present. The end thrust in well designed turbines is usually of small amount and seldom causes trouble. These bearings are usually flooded with oil and are often made with bronze rings which can easily be replaced in case of damage.

Several builders of impulse-reaction turbines have substituted an oil thrust piston for the steam balance piston of the usual form. This piston is placed on the governor end of the shaft outside of the casing proper. The thrust is taken up by oil which is supplied under pressure and which can escape only through sets of labyrinth baffles on the piston and on the surrounding chamber. The piston adjusts itself for the amount of thrust present by a small axial movement of the shaft, thus opening or closing the discharge area for the oil through the labyrinth baffles, and automatically varies the oil pressure on the face of the piston. This arrangement does away with the loss of steam through balance pistons and should improve the turbine efficiency, though a small amount of power is required to pump the oil.

DIMENSIONS OF HORIZONTAL CROSS-COMPOUND CORLISS ENGINES*

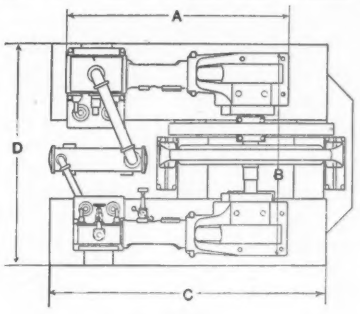


TABLE II.

Size of Cylinder.			Approx. Capacity Generator in Kw.	A	B	C	D
Diam. H P.	Diam L. P.	Stroke.					
12	24	30	200	18 ft. 3 in.	15 ft. 7 in.	22 ft. 0 in.	19 ft. 0 in.
12	24	36		18 ft. 9 in.	16 ft 8 in.	23 ft. 0 in.	19 ft. 6 in.
14	28	30	300	18 ft. 4 in.	15 ft. 8 in.	24 ft. 6 in.	19 ft. 0 in.
14	28	36		18 ft. 10 in.	16 ft. 8 in.	25 ft. 0 in.	19 ft. 6 in.
16	32	36	400	19 ft. 7 in.	17 ft. 0 in.	26 ft. 6 in.	20 ft. 0 in.
16	32	42		22 ft. 3 in.	17 ft. 6 in.	27 ft. 6 in.	20 ft. 6 in.
18	36	36	500	19 ft. 9 in.	17 ft. 5 in.	27 ft. 0 in.	20 ft. 6 in.
18	36	42		22 ft. 6 in.	16 ft. 0 in.	28 ft. 6 in.	21 ft. 6 in.
18	36	48		25 ft. 3 in.	18 ft. 7 in.	30 ft. 0 in.	22 ft. 3 in.
20	40	36	500	20 ft. 0 in.	19 ft. 6 in.	26 ft. 6 in.	22 ft. 6 in.
20	40	42		22 ft. 6 in	19 ft. 10 in.	29 ft. 0 in.	23 ft. 0 in.
20	40	48		25 ft. 0 in.	20 ft. 5 in.	31 ft. 0 in.	23 ft. 9 in.
22	44	36	750	20 ft. 9 in.	19 ft. 10 in.	27 ft. 6 in.	23 ft. 6 in.
22	44	42		23 ft. 3 in.	21 ft. 2 in.	30 ft. 0 in.	24 ft. 3 in.
22	44	48		25 ft. 8 in.	21 ft. 4 in.	32 ft. 6 in.	25 ft. 0 in.
24	48	42	750	24 ft. 6 in.	22 ft. 3 in.	30 ft. 6 in.	25 ft. 2 in.
24	48	48		27 ft. 0 in.	23 ft. 0 in.	33 ft. 0 in.	26 ft. 0 in.
26	52	42	1,000	24 ft. 8 in.	23 ft. 8 in.	30 ft. 6 in.	26 ft. 10 in.
26	52	48		27 ft. 2 in.	24 ft. 4 in.	33 ft. 0 in.	27 ft. 6 in.
26	52	60		32 ft. 2 in.	24 ft. 10 in.	36 ft. 0 in.	28 ft. 0 in.
28	56	48	1,000	27 ft. 6 in.	25 ft. 10 in.	34 ft. 6 in.	29 ft. 6 in.
28	56	60		32 ft. 6 in.	26 ft. 4 in.	39 ft. 0 in.	30 ft. 0 in.
30	60	48	1,250	27 ft. 9 in.	26 ft. 4 in.	35 ft. 0 in.	30 ft. 6 in.
30	60	60		32 ft. 9 in.	27 ft. 4 in.	40 ft. 0 in.	31 ft. 6 in.
32	64	60	1,500	33 ft. 0 in.	28 ft. 10 in.	41 ft. 0 in.	33 ft. 0 in.
34	68	60	1,750	33 ft. 0 in.	29 ft. 1 in.	43 ft. 0 in.	34 ft. 10 in.
36	72	60	2,000	33 ft. 6 in.	29 ft. 6 in.	44 ft. 0 in.	36 ft. 6 in.

SUPERHEATED STEAM FOR TURBINES

FROM the time that steam turbines first came into use, it has been recognized that at least a moderate degree of superheat could be used to advantage; the question which has naturally arisen is how much? This can be answered correctly only after tests of the turbine have been made, since it varies with different makes and sizes of turbines.

In reciprocating engines, as has been pointed out, the great advantage of superheat is to overcome initial condensation, but the turbine has no initial condensa-

*From Steam Turbines by French.

tion, as the term is used in connection with reciprocating engines, as there is no change of temperature of the various parts or stages of the turbine.

Gain in economy by the use of superheated steam in turbines is due principally to the reduction of friction of the steam as it passes through the blades. As soon as saturated steam begins to expand among the

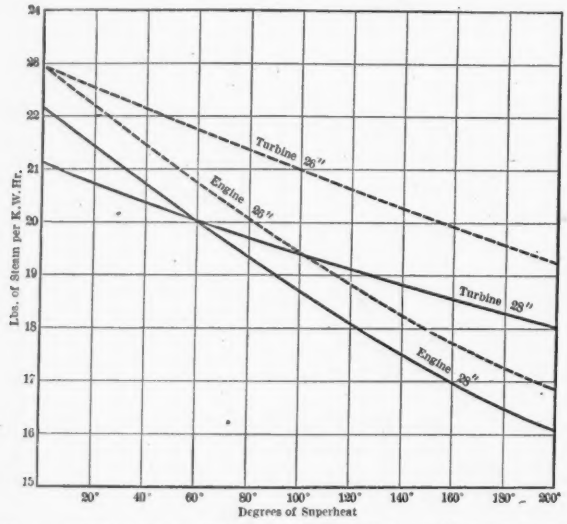


FIG. 1. EFFECT OF SUPERHEAT ON THE STEAM CONSTRUCTION OF TURBINES AND ENGINES

turbine blades, it begins to condense and the friction of this vapor against the blades retards its flow greatly and at the same time, with the exceedingly high speed at which it is flowing, is apt to score and wear the blades badly. To overcome these difficulties, superheating is resorted to.

Theoretically, it would seem that the amount of this superheat should be enough to deliver the exhaust

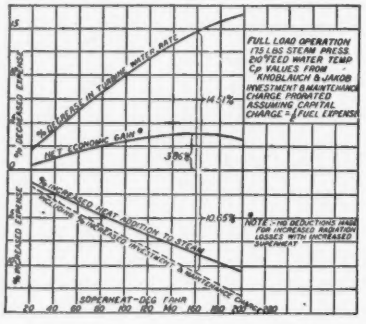


FIG. 2. NET ECONOMY IN THE USE OF SUPERHEATED STEAM WITH TURBINES

to the condenser in a saturated condition, but this is impossible, from a practical standpoint at least, as will be evident from the chart, Fig. 3, page 87. plotted by Lester G. French, which shows the pressure at which superheated steam becomes saturated during adiabatic expansion.

Based on tests of Curtis, Parsons, Zoelly and Brown-Boveri turbines, the curves shown in Fig. 1 give the effect of superheat upon steam consumption of turbines and engines with different degrees of vacuum. The curves for the turbines would confirm the statement of Parsons and other authorities that the gain in economy of steam is about 1 per cent for every 10 deg. of superheat up to about 150 or 180 deg. F.

While this shows well for the use of superheat, it will be recognized that the extra expense for equipment and production of superheated steam reduce the net economy as the degree of superheat is increased. This net economy gain as shown in Fig. 5, calculated for the Westinghouse Electric and Mfg. Co., would indicate that with 175 lb. steam pressure the most economical superheat to employ is 160 deg. F. Moderate working conditions at present are in the neighborhood of 175 lb. gage pressure, 100 deg. superheat and 28-in. vacuum.

USE OF GONDENSERS WITH STEAM TURBINES

How Vacuum Helps; the Most Economical Amount to Use, Condensing Water needed and Condenser Required, Cooling Surface

TO secure at least part of the energy that exists in steam at atmospheric pressure the use of a condenser is resorted to, whether it be an engine or a turbine that is used for converting the heat energy into mechanical power. The amount of energy, however, that can be economically secured by a turbine from steam at atmospheric pressure is greatly in excess of that possible with a reciprocating engine.

The extent to which the vacuum may be carried is limited by the inital temperature of the cooling water

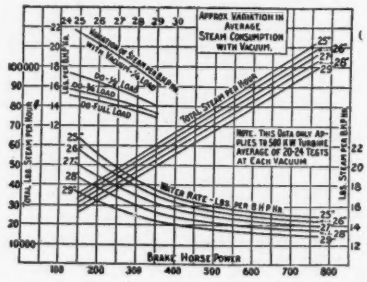


FIG. 1. VARIATION IN STEAM CONSUMPTION OF TURBINE DUE TO CHANGE OF VACUUM

and the expense of installing and running the condenser to maintain the highest vacuum. This expense is due to increased capacity of the condensing outfit, and the necessity of maintaining a lower temperature of discharge water, which means an increase in the amount of water used.

A specific case, the principle of which, however, applies generally, is summarized in Fig. 2 by the Westinghouse Co. For each vacuum included, the turbine economy was based upon the assumption that the unit should be designed especially for that condition as opposed to taking a given turbine and operating it under the varying conditions selected. The water was taken at 55 deg. F. and surface condensers were used. On a conservative basis, the best results, as shown here, are obtained between 28 and 28.5 in. vacuum. Taking into account the increasing cost and maintenance of tubes there is little inducement to aim for a higher vacuum than 28 in.

The saving in steam at different vacuums and per cent of full load is well illustrated in Fig. 1. These curves are plotted from the results of 20 to 40 tests on

500-kw. Westinghouse-Parsons turbines and apply only to that size and type of turbine, using dry steam. The effect of vacuum, however, is clearly shown and gives a general idea of what may be expected from other turbines.

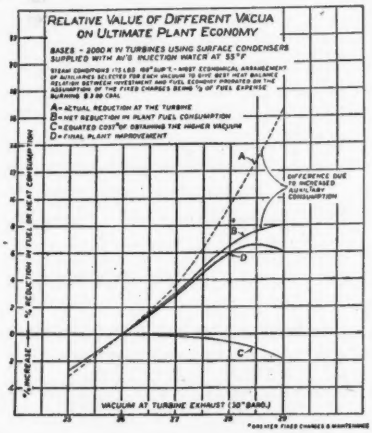

RELATIVE VALUE OF DIFFERENT VACUA ON ULTIMATE PLANT ECONOMY
BASES - 2000 K W IN TURBINES USING SURFACE CONDENSERS SUPPLIED WITH 60° INJECTION WATER AT 55° F
A = ACTUAL REDUCTION AT THE TURBINE
B = NET REDUCTION IN PLANT FUEL CONSUMPTION
C = EQUATED COST OF OBTAINING THE HIGHER VACUUM
D = FINAL PLANT IMPROVEMENT
DIFFERENCE DUE TO INCREASED AUXILIARY CONSUMPTION
% INCREASE — % REDUCTION IN FUEL OR HEAT CONSUMPTION
VACUUM AT TURBINE EXHAUST (30" BARO.)

FIG. 2. PLANT ECONOMY AT VARYING DEGREES OF VACUUM

The amount of water used for condensing purposes depends somewhat upon the type of condenser. In the jet condenser, the water mingles with the exhaust steam so that condensed steam and cooling water

(Barometer 29.92.)

Temp. of Injection Water.	Vacuum 24". Temperature of Steam 141°. Temperature of Hot Well.					Temp. of Injection Water.	Vacuum 25". Temperature of Steam 134°. Temperature of Hot Well.				
	110	115	120	125	130		105	110	115	120	125
40	3.1	3.3	3.5	3.7	4.0	40	3.3	3 5	3.7	4.0	4.4
50	3.3	3.5	3.7	4.0	4.3	50	3.5	3.7	4,0	4.3	4.7
60	3.7	3.8	4.0	4.2	4.6	60	3.8	4 0	4 3	4.6	5 1
70	3.9	4.1	4.3	4.6	5.0	70	4.1	4.4	4.7	5.1	5.5
80	4.1	4.4	4.7	5.0	5.5	80	4.5	4.8	5.2	5.6	6.1
90	4.4	4.8	5.1	5.5	6.0	90	5.1	5.4	5.8	6.2	6 9

Temp. of Injection Water.	Vacuum 26". Temperature of Steam 125°. Temperature of Hot Well.					Temp. of Injection Water.	Vacuum 27". Temperature of Steam 114°. Temperature of Hot Well.				
	100	105	110	115			90	95	100	105	
40	3.6	3.9	4.2	4.6	.....	40	4.1	4.4	4.7	5.1	.....
50	3.8	4.2	4.6	5.0	.....	50	4.4	4.7	5.1	5.6	.....
60	4.2	4.6	5.0	5.4	.....	60	4.8	5.2	5.0	6.2	.....
70	4.6	5.1	5.4	6.0	.....	70	5.4	5.8	6.3	7.0	.....
80	5.1	5.6	6.1	6.7	.....	80	.....	6 7	7 2	8.0	.....

Temp. of Injection Water.	Vacuum 28". Temperature of Steam 100°. Temperature of Hot Well.					Temp. of Injection Water.	Vacuum 29". Temperature of Steam 77°. Temperature of Hot Well.				
	75	80	85	90			60	65	70		
40	4.6	4.9	5.3	5.8	.....	35	6.3	6 9	7.7	.....	.....
50	5.0	5.4	5.8	6.4	.....	40	6.8	7 4	8.3	.....	.....
60	5.5	6.1	6.6	7.3	.....	45	7.4	8.0	9 0	.....	.....
70	.....	.....	7.7	8.5	.....	50	.....	8.9	9.9	.....	.....

Final temperature of injection water assumed to be 10 degrees lower than that of the hot-well.

FIG. 3. SQUARE FEET OF COOLING SURFACE NECESSARY TO CONDENSE 1 LB. OF STEAM PER MINUTE

come to the same final temperature. Thus the amount of water needed depends upon the initial temperature of the cooling water, the temperature of the discharge water and the temperature of the steam entering the condenser, and may be found by subtracting from the total heat of the steam above 0 deg. F. the temperature of the discharge water and dividing this difference by the difference between the initial and final temperatures of the cooling water; the result will be the weight in pounds of the cooling water necessary to condense and cool 1 lb. of steam to the required discharge temperature.

For surface condensers the amount of water required for each pound of steam is dependent upon the initial and final temperatures of the cooling water, the degree of vacuum and the temperature of the condensed steam. The amount of water needed may be closely approximated by subtracting from the total heat of the exhaust steam above 0 deg. F. the temperature of the condensed steam and dividing the remainder by the temperature range of the cooling water; the result will be the pounds of water required per pound of steam.

The cooling surface needed in surface condensers depend upon so many variable factors that a simple rule which would apply generally can hardly be given, a table, computed by Gebhardt is, however, given herewith from which the square feet of surface required to condense 1 lb. of steam a minute can be obtained for all ordinary conditions of operation.

THE REGENERATOR

Its Application to the Low-Pressure Steam Turbine

FOR low-pressure turbines, there are 2 general classes of operation; where the steam supply is substantially constant or varies with the turbine load as in power station service, and where the steam supply is widely fluctuating or intermittent which is exemplified in rolling mill service, forging plants, mine hoists, etc.

Engines for such service use great quantities of

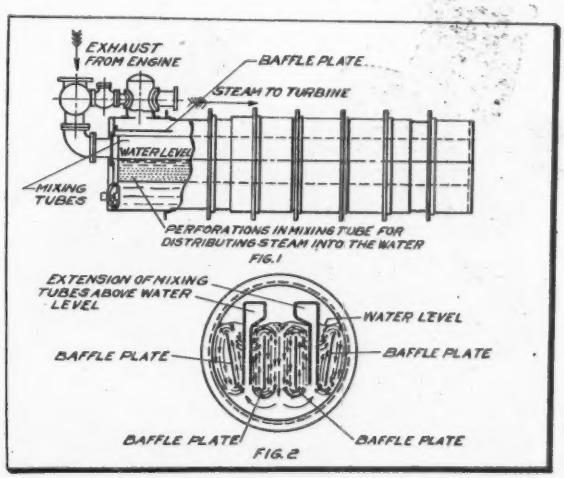


FIG. 1. SIDE VIEW OF RATEAU REGENERATOR
FIG. 2. CROSS-SECTION OF RATEAU REGENERATOR

steam under widely varying loads often with little or no expansion. To equalize the steam supply from these constantly varying sources, a steam accumulator has been developed, as shown in Figs. 1 and 2. When it arrives in large quantities, the engine exhaust is condensed in the generator at about atmospheric pressure, and is revaporized when the excess ceases. Condensation and re-evaporation of the steam follow the fluctuations of pressure as the supply exceeds or falls short of that required by the turbine.

Regenerators are cylindrical in form, with the water kept in forced circulation by the injection of steam or mechanically. The steam flow from the regenerator to the turbine is constant compared to that from the engine to the regenerator and is substantially equal to the average rate of engine exhaust.

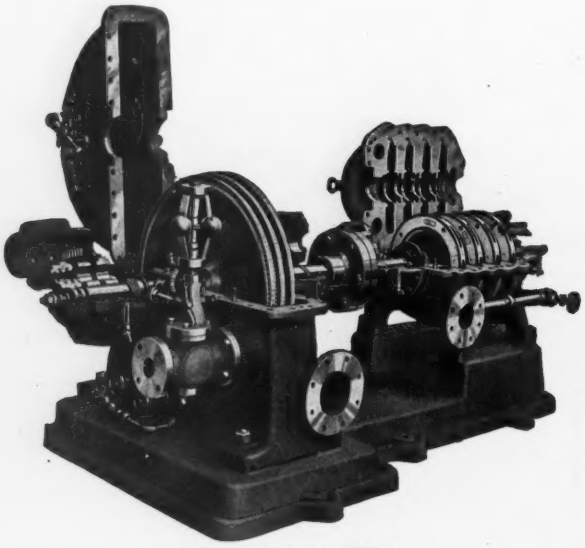
Several accessories are used with the regenerator which are essential to its successful operation. An automatic relief valve is provided which allows the steam from the engine to escape into the atmosphere or condenser, if the turbine should not require all the steam exhausted by the main engine. An automatic expansion valve is also provided so that live steam from the boiler can be used for operating the turbine should the engine for any cause be temporarily shut down or if sufficient exhaust steam is not available.

Generally a steam check valve and a water check valve are provided; the former for shutting off the accumulator from the turbine when the main engine is shut down and the turbine is supplied with live steam only; while the latter is used to prevent the water in the accumulator returning toward the engine through the exhaust supply pipe, when the engine is shut down.

ALBERGER STEAM TURBINE

Alberger Pump and Condenser Co., New York City

ALBERGER steam turbines are of the impulse type; the steam is expanded from the initial pressure down to exhaust pressure by means of an expansion nozzle, thereby converting the entire energy of the



SIDE SECTIONAL VIEW

steam above exhaust pressure into velocity. The high velocity steam is properly guided by means of the nozzle against the comparatively slow moving vanes of the turbine wheel whereby it is reversed in direction and reduced in velocity, while giving up part of its energy to the wheel. On leaving the wheel vanes, the steam is received in suitable passages and again reversed in direction and properly guided against the moving wheel vanes a second time, thus giving up a further portion of its energy. This operation is repeated until practically the entire energy of the steam has been absorbed by the wheel.

The turbine casing is of cast iron, annular in form and made in one piece provided with a removable head, making a male and female fit, which will allow the interior parts of the turbine to be readily inspected or removed. The exhaust steam opening is in the lower part of the casing. Suitable brackets are provided for the support of the shaft bearings and feet for attaching to the bedplate. The bearings are similar to those used on the Alberger pump, one on either side of the casing and entirely removed from all contact with the steam.

Turbine wheels and reinforcing rings are made of chrome steel; the vanes are of a special bronze not affected by moisture in the steam and they are so secured to the wheel that the whole is practically one piece with no chance of the vanes becoming loose. The governor is of the throttling type, driven by worm gearings from the main shaft. It is a slow speed governor provided with a speed adjusting device.

DE LAVAL MULTI-STAGE STEAM TURBINE

De Laval Steam Turbine Co., Trenton, N. J.

IN the De Laval multi-stage turbine, Fig. 1, the rotating member consists of a heavy shaft upon which is mounted a series of disks or wheels, each revolving in an independent chamber formed between diaphragms held in a cylindrical casing. Steam is admitted to the steam chest at the right hand end of the casing, flows through nozzles and impinges upon the buckets of the first wheel.

Nozzles employed in the first stage are formed of bored and reamed tubes set in the nozzle ring, or they may be bored and reamed directly in the nozzle ring itself. The nozzles of this stage occupy only a portion of the circumference, to allow longer blade lengths. Any or all of these nozzles may be controlled by hand-operated valves seating upon the inlet openings, to admit more or less steam as the load changes greatly at different periods.

Buckets against which the steam impinges have the tips with lugs which fit against similar projections on the adjacent buckets, forming a continuous rim, which prevents spilling by confining the jets of steam within closed channels.

Buckets are secured to the rim of the wheel by transverse dovetails, which permits the removal or insertion of individual buckets without disturbing others.

Increase in the cross-sectional area of the passages required by the expansion of the steam as it proceeds through the turbine is gained by lengthening the blades, reducing the diameters of the wheels correspondingly and increasing the bore of the casing.

Wheels upon which the buckets are mounted consist of steel disks, mounted on the shaft by means of taper bushings. The hub of each wheel is so extended that the hubs of adjacent wheels touch one another, permitting them to be locked in place by one nut.

With the exception of the nozzles in the initial stage, the nozzles of each succeeding stage are formed between guide vanes set around the entire periphery of the diaphragm. They are spaced and located upon the rim of the diaphragm by pins and are held in place by a solid steel band shrunk over their tips. Two pins are used for each vane to determine its proper angle, and therefore, in connection with the shape of the vanes, to fix the contour and the cross sectional area of

the nozzles formed between the successive vanes. The cast-iron diaphragm disks are perforated at the center and are fitted with removable labyrinth packings in order to minimize the leakage of the steam from stage to stage between the diaphragms and the cylindrical wheel hubs.

The heavy rings surrounding the guide vanes and diaphragms rest in a cast-iron wheel case, which is split horizontally to render all working parts of the turbine readily accessible. Leakage from the first cell outward to the atmosphere is first obstructed by a labyrinth packing of double length, any steam leaking past this packing being led back to an intermediate stage and utilized at a lower pressure for generating power. Following the labyrinth packing is a series of segmental carbon ring packings, each ring being enclosed in a separate compartment.

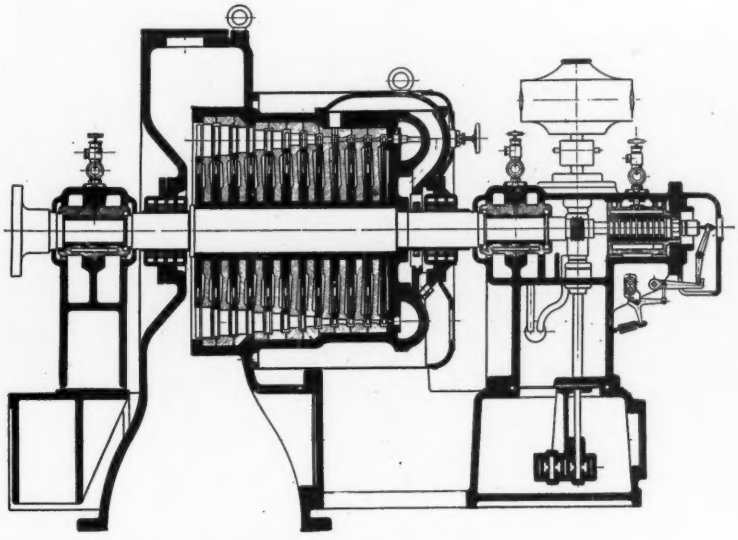


FIG. 1. AXIAL SECTION SHOWING GENERAL ARRANGEMENT OF PARTS

Leakage past the first carbon ring is carried back to the exhaust connection or to an intermediate stage of the low pressure packing. Live steam is introduced between the 2 outer carbon rings so that any leakage inward along the shaft will be of steam, not air. At the exhaust end similar construction is employed.

There are 3 bearings in the multi-stage turbine, 2 supporting the weight of the revolving parts and the third a thrust bearing. The bearing shells are made of cast iron, babbit lined, bored and reamed to standard dimensions. Each bearing is arranged for water cooling to insure continuous operation at a low temperature.

Mounted upon a vertical shaft driven from the turbine shaft by worm gearing, is the speed regulating governor of the Jahns type. Movement of the sliding sleeve on the spindle is effected by bell cranks engaging both the weights and the sleeve through roller bearing connections. The races of the bell crank roller bearings are so arranged that the governor possesses constant energy for any position of its stroke, and any desired coefficient of fluctuation may be obtained, therefore, without danger of instability in any position.

THE ECONOMY STEAM TURBINE

Kerr Turbine Co., Wellsville, N. Y.

ECONOMY turbines embody a simple form of construction. The nozzles are formed by Monel metal vanes cast into the diaphragms which direct the flow of the steam into Monel metal buckets where the usual reversal of direction of flow takes place. These turbines are built in multistage form, generally with from 2 to 10 stages, as may be desirable for different conditions of steam pressure and vacuum, and for desired steam consumption rates at varying speeds.

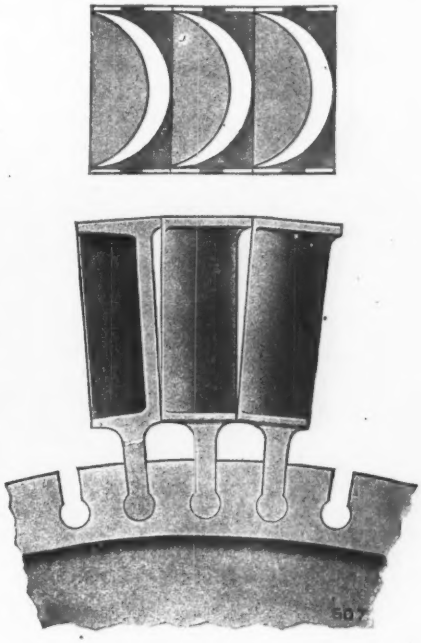


FIG. 4. METHOD OF FASTENING BUCKETS

Referring to the diagram, Fig. 1, each set of nozzles discharges onto a separate bucket wheel, steam entering the bucket at the side of the wheel, and passing through the bucket in a direction parallel to the tur-

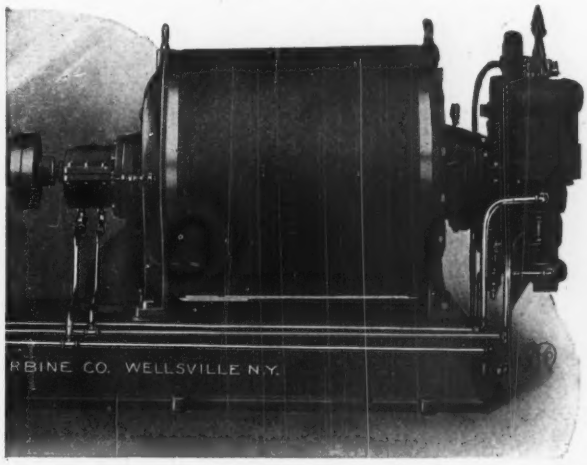


FIG. 2. A TYPICAL ECONOMY TURBINE

bine shaft; one set of nozzles and one wheel constitute a stage. Steam issuing from the nozzle of the first stage, impinges upon the first stage buckets, leaving within the first stage casing a considerable pressure to be expanded through the second stage nozzles upon the second stage buckets and so on through the machine. In this way, the total pressure drop is divided into as many steps as there are stages. The energy abstracted from the steam at each stage is comparatively small and the jet velocity in all stages is kept at a low figure.

With a constant load and initial pressure, and if the terminal pressure is unchanged, the amount of steam passing through the turbine is constant. Lowering the speed lowers the capacity of the turbine and increases the steam consumption in inverse proportion to the change of speed.

This compounding by single impulse stages permits large radial clearances over the outside diameter of the wheels, and as the pressure of the steam as it leaves the nozzle is the same as the stage pressure, there is little tendency to spill. For the same reason the side clearance between the buckets and nozzles can be anything up to ⅛ or 3/16 in. without appreciable decrease of efficiency.

The Economy turbine for high pressure steam can be designed to develop a given power with any steam pressure above 75 lb. by properly proportioning the nozzle areas to suit the given pressure, but as the brake horsepower developed by a given turbine is approximately in proportion to the initial steam pressure, the higher the steam pressures, say from 150 to 200 lb. are usually advisable for best efficiency.

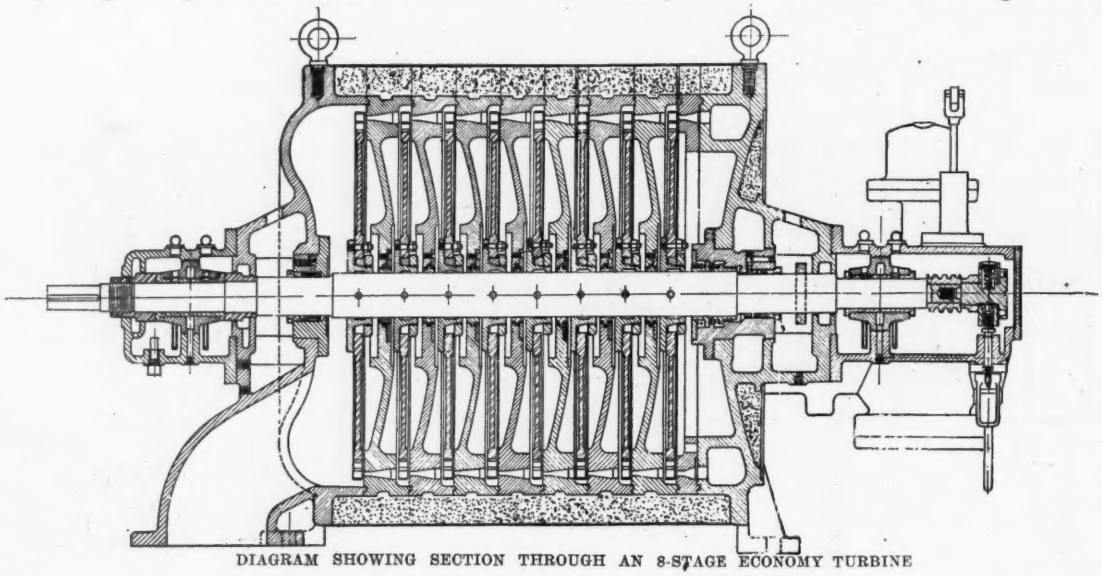


DIAGRAM SHOWING SECTION THROUGH AN 8-STAGE ECONOMY TURBINE

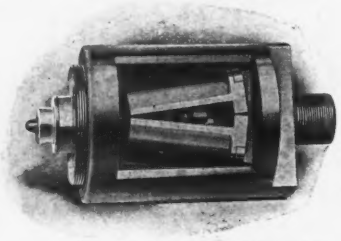


FIG. 2. STURTEVANT GOVERNOR

STURTEVANT STEAM TURBINES

B. F. Sturtevant Co., Hyde Park, Mass.

THE new Sturtevant Type 5 steam turbine is of the single stage, multi-impulse type. By suitable combinations of steam pressure, size of rotor, nozzle capacity and rotative speed, the present range of from 5 to 250 hp. is obtainable. The turbines are regularly made with rotor diameters of 12, 18, 24, 30 and 36 in.

Steam enters an annular chamber in the casing of the turbine through a balanced throttle valve. From this chamber it is expanded through nozzles to the exhaust pressure of the turbine, leaving the nozzles at a high velocity and impinging against the rotor, the rim of which contains semicircular milled buckets. Owing to their shape, these buckets reverse the direction of the steam, driving it back into a set of stationary buckets which return it to the rotor. Thus the steam is returned to the rotor several times by the

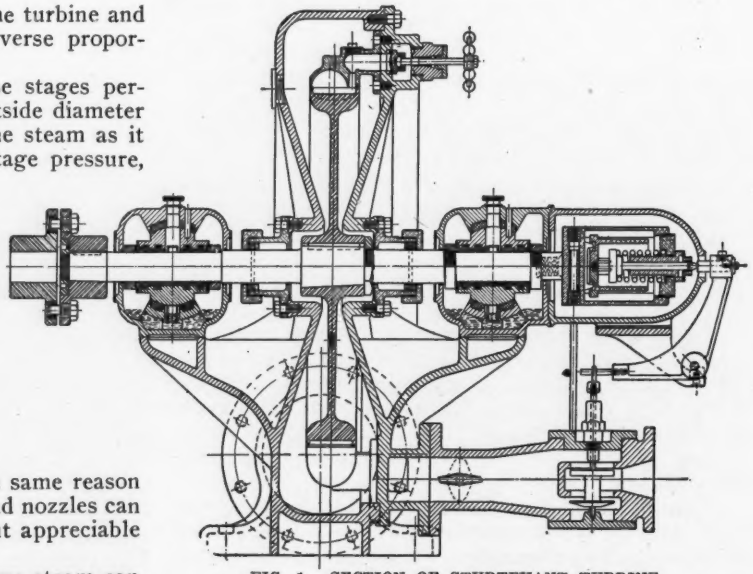


FIG. 1. SECTION OF STURTEVANT TURBINE

action of the reversing buckets before its velocity has finally dropped to the velocity of the rotor and its kinetic energy has been practically absorbed. It then passes into the exhaust.

The casing is built of 2 high-grade iron castings split vertically. All joints are ground so as to be steam tight, obviating the necessity of gaskets. One-half of this casing is known as the steam head, within which is cored the steam chamber. The bearing brackets are cast integral with the casing, giving compactness and eliminating the necessity for separate foundation.

Nozzles and buckets are cast together in Tobin bronze, and bolted to the inside of the steam head, the number used in each turbine depending upon the power required. Directly behind the nozzle is a supplementary bucket which catches any steam escaping from the nozzle over the back of the first bucket, thus lowering the steam consumption of the turbine, especially when running at low speeds when the "spill" from the nozzle is necessarily greatest.

The nozzles are equipped with individual shut-off valves, hand-operated from the exterior of the casing, so that for continuous light load one or more of these valves may be closed.

Bearings are generously proportioned and abundantly supplied with oil from large oil pockets, so designed that no dirt can get in and no oil leak out. The oil is taken from the reservoir by a channel shaped oiling ring and is held within the ring by centrifugal force until it is diverted to the bearing by a scoop.

The turbine speed is governed through a balanced throttle valve by means of a centrifugal governor on the end of the rotor shaft, while a separate emergency governor operates a separate valve to stop the turbine if speed should exceed a predetermined maximum.

Metallic packing, used to prevent the leakage of steam between shaft and casing, is practically frictionless and requires no lubrication; it will hold steam tight against any back pressures to which the turbine may be subjected. The stuffing-box holding this packing is of the floating type, with ground joint against the casing of the turbine. Springs under the bolt heads allow the 2 ground surfaces considerable lateral play so that the stuffing-box follows the slight movements of the shaft due to unequal expansion or contraction, and the packing remains tight.

CURTIS STEAM TURBINES

General Electric Co., Schenectady, N. Y.

CURTIS steam turbines act by impulse having the steam expanded in stationary nozzles, acquiring relatively high velocity, and then passing through movable and stationary buckets without further expansion. Figure 1, page 88, shows diagrammatically the progress of the steam.

Entering at A from the steam pipe, it passes into the steam chest B, and then through one or more open valves, the number being controlled by the governor according to the load to the bowls C; thence, the steam expands through divergent nozzles D entering the first row of revolving buckets of the first stage at E, and passing through the stationary buckets F, which reverse its direction and redirect it against the second revolving row G.

This constitutes the performance of the steam in one stage, or pressure chamber. Having entered the first row of buckets at E with relatively high velocity it leaves the last row G with a relatively low velocity, its energy between the limits of inlet and discharge pressure having been abstracted in passing from C to H. It has, however, a large amount of unexpended energy, since the expansion from C to E has covered only a part of the available pressure range. The expansion process is, therefore, repeated in a second stage precisely as in the first stage through bowls H, nozzles I and brakes K, L and M. Again the velocity acquired in the nozzles is expended in passing through the moving and stationary buckets and the steam leaves the second row M with relatively low velocity. This process is continued up to 6 or 7 stages in the larger machines.

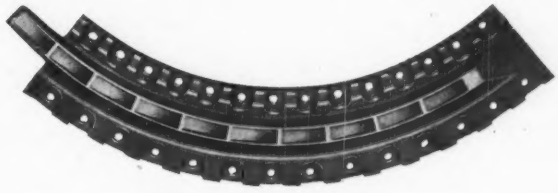


FIG. 1. ARRANGEMENT OF NOZZLES OF A SINGLE CURTIS STAGE

As the steam expands from stage to stage, its volume rapidly increases, and a greater area of steam passage must be provided; this is accomplished in 2 ways; first, by increasing the height of the buckets and second by increasing the number and area of nozzles from stage to stage. It should be noted that the primary admission nozzles D actually extend around

FIG. 2. CURTIS TURBINE WHEEL

only a small portion of the first stage periphery, therefore only those buckets adjacent to the nozzles at any instant are carrying active steam.

This applies equally to the stationary row and second revolving row; in fact, the stationary or intermediate buckets, as built, extend over a small arc not much longer than the nozzle arc. In the second stage, however, the nozzle arc becomes longer and wider, thus permitting the flow of steam through a greater number of revolving buckets and necessitating a longer arc of stationary buckets. Finally, when the low-pressure stages are reached, the nozzles and stationary buckets extend all the way around the circumference.

Greater area for the steam flow is also provided by increasing the bucket length. For example, the first stage, or high-pressure buckets, are generally less than an inch long, while those in the low pressure stages may be 8 or 10 in. in length.

This lengthening of buckets from one stage to the next to assist in providing proper space for the passage of the expanding steam should not, however, be confused with the difference in size of the 2 rows in any given stage. Figure 1 shows diagrammatically a typical relation of moving and stationary buckets. in any one stage; A and C are the moving and B the stationary buckets. It will be observed that B and C are progressively longer than A, and that the ends of the revolving, and the base of the stationary, buckets form a diagonal line diverging from the parallel, but this is not to provide for expansion and increasing volume.

Steam enters bucket A at high velocity, and leaves bucket C at a comparatively low velocity. In its passage a continuous drop in velocity has taken place, therefore, a wider passage, and consequently a longer

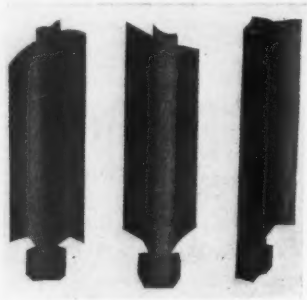


FIG. 3. INDIVIDUAL BUCKETS

bucket is necessary. We may compare this with the flow of water or other non-expansive fluid through a funnel or cone shaped passage.

If the passage be filled with moving liquid passing from the small to the large end, the velocity will be high at the entrance end, but relatively low at the discharge end. The liquid has thus considerably dropped in velocity, but without expansion or increase in volume.

Briefly, then, the Curtis turbine derives its energy from the expansion of steam in a series of steps or stages. Each stage may contain 2 or more rows of rotating buckets with stationary reversing buckets between them. The steam passes through the buckets of any one stage by velocity only, there being practically no expansion in the stage. The actual expansion is accomplished in the nozzle passages between stages.

Curtis turbine wheels consist of steel disks, carrying the rotating buckets on their periphery. In some cases the 2 rows of buckets are carried on separate disks, and in others by a single disk, the buckets being held in the periphery by a dovetail root which fits snugly into a channel of the same section machined in the rim. Figure 1 shows this in section and Fig. 2 shows the wheel rim with a row of buckets partially inserted. At intervals the dovetail channel is opened for the insertion of buckets as shown at A, these openings being afterward filled with a spacing block, and closed up. After the buckets are assembled, a shroud ring, shown at B-B, is riveted to their outer ends, partly to stiffen the complete row and reduce vibration, but more especially to assist in retaining the steam flow in the bucket space. Individual buckets in Fig. 3 show the heavy dovetail root, at one end, and the tenon designed for riveting on the shroud ring at the other. Figure 4 is a typical section of expanding nozzles.

Oil is supplied to the bearings from a general oil distributing system, usually supplied in vertical machines from independently driven oil pumps, and in horizontal machines from a small pump geared to the

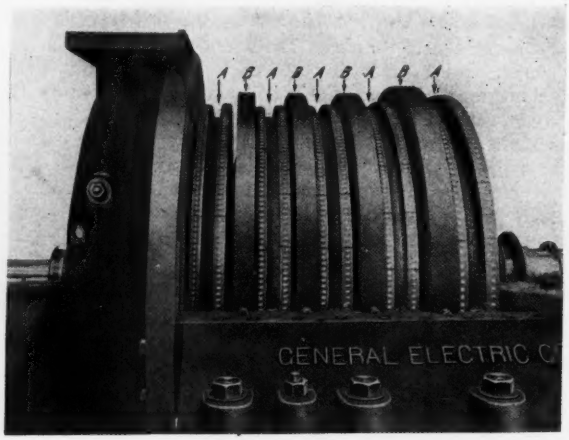


FIG. 4. HORIZONTAL 5-STAGE CURTIS STEAM TURBINE WITH TOP HALF OF CASING REMOVED

turbine shaft. Such small end thrust as may exist is taken up by a simple roller thrust bearing in horizontal machines, and by the step bearing in vertical machines.

Motion is transmitted through a connecting rod to the valve mechanism which actuates the valves by a governor of the centrifugal type. The device to prevent acceleration from any cause beyond a certain predetermined speed limit consists of a ring unevenly weighted, attached to and revolving with the shaft. At normal speeds and less, the unbalanced ring is held concentric with the shaft by suitable springs, but at excess speed, the centrifugal force overcomes the spring tension, and the ring revolves eccentrically, tripping the valve mechanism and causing the main throttle valve to close instantly, thereby shutting off the steam supply.

TERRY LOW-SPEED STEAM TURBINE

The Terry Steam Turbine Co., Hartford, Conn.

TERRY turbines are of the compound velocity stage impulse type in which energy is delivered to the wheel as useful work in the following manner:

The wheel is fitted with semicircular buckets as shown in Fig. 1; steam escaping from the jet strikes one side of the bucket and in leaving the opposite side of the same bucket is reversed in direction. It then enters the first stationary bucket or reversing chamber, which directs the steam back again into another bucket of the same wheel at a point adjacent to the jet; this operation is repeated as many times as is necessary for the complete utilization of all the available energy in the steam, its velocity energy being extracted in these reversals. As the flow of steam

into and from the buckets is always in a plane at right-angles to the shaft there is no end thrust.

Increased power for a turbine wheel of given diameter is obtained by fitting additional jets and reversing chambers in the casing, each jet being supplied with live steam. With this arrangement partial load may be carried with full load efficiency, for one or more of these jets may be turned off by hand-operated

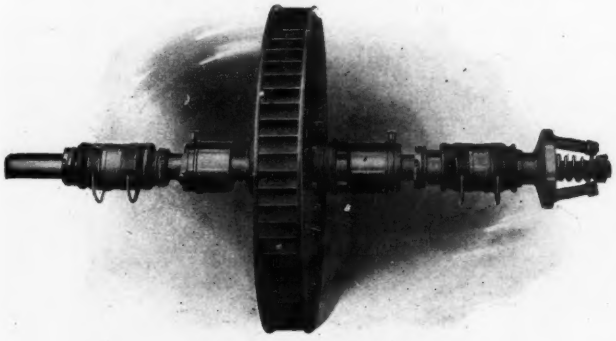


FIG. 1. ROTOR OF TERRY STEAM TURBINE

valves. Casing and bearings are parted horizontally so that the entire turbine is open for inspection by merely lifting the cover, this is accomplished without disturbing the steam and exhaust connections.

Mounted directly on the turbine shaft is the fly-ball governor which controls a specially constructed

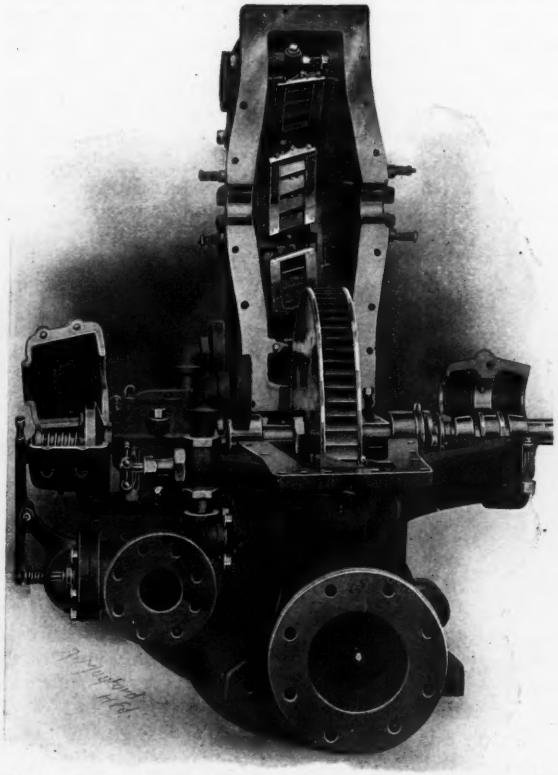


FIG. 2. SINGLE-STAGE TERRY TURBINE WITH COVERS LIFTED

mitre throttle valve. As there is no gearing for the governor, the necessity of an emergency governor is so slight that none is fitted with the standard design. Bearings are supported by brackets from the turbine casing. In the small sizes they are made of phosphor bronze, in one piece, while in the larger sizes they have a bearing shell lined with babbit metal.

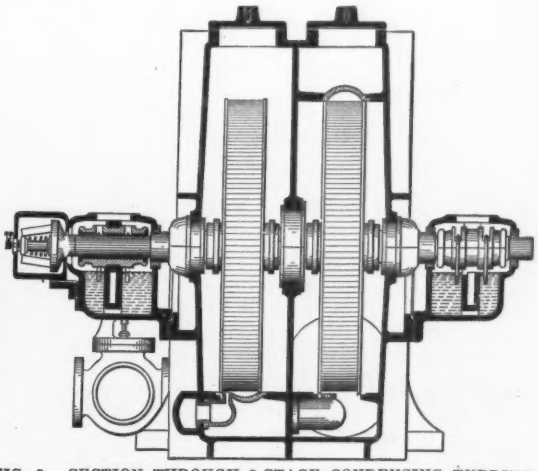


FIG. 3. SECTION THROUGH 2-STAGE CONDENSING TURBINE

While the economy of the smaller sizes of the single-stage turbine is considerably improved when operated condensing, better efficiency may be obtained by compounding. In a compound turbine, the steam is expanded to atmospheric pressure in the jets of the first stage, subjecting this casing and gland to atmospheric pressure only. Similarly in the second stage the steam is expanded from atmospheric pressure to the condenser vacuum, and the casing and steam sealed glands have only to withstand an external pressure corresponding to the vacuum.

WESTINGHOUSE STEAM TURBINES

The Westinghouse Machine Co., East Pittsburgh, Pa.

WESTINGHOUSE rotors are built up of hollow steel shafts or drums, which are machined on the inside as well as on the outside; the shaft sections are enlarged at one end and securely fixed in the drums. The

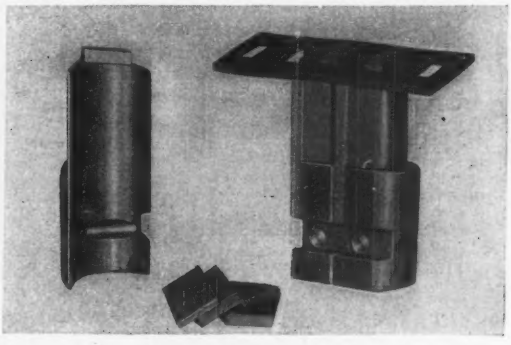


FIG. 1. IMPULSE BLADING

drum diameter corresponds to the root diameter of the smallest rings of blading, the large diameters of blading sections being mounted in groups on separate steel drums which are balanced and pressed on the central drum. The thrust "dummies" on the single-flow and semi-double-flow designs are also made up of separate steel rings pressed on the central drum so that if they should be injured by careless adjustments,

they can be easily removed and replaced by new ones.

Westinghouse impulse blading is shown in detail in Fig. 1. The blades are separated by steel packing pieces, and blades and packing pieces are locked together by steel pins, as shown in the illustration.

Grooves in the impulse wheel are somewhat wider than the blades, and have an overhanging shoulder on one side. The blades and packing pieces are notched on one side, and when in place the notches engage with the overhanging shoulder on the one side of the ring groove. The other side of the ring groove is slightly undercut in dovetail fashion. When the blades

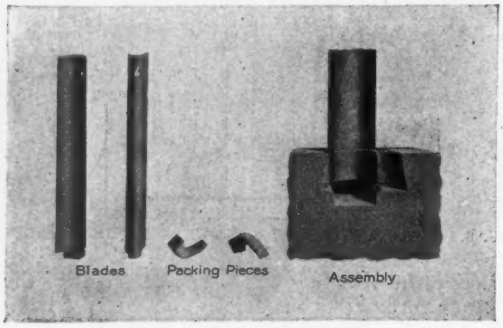


FIG. 2. REACTION BLADING

and packing pieces are set in their grooves, the space between the blades and the dovetail side of the groove is filled in with a series of pairs of steel wedges, which are beveled lengthwise and crosswise, so that when set up in pairs they fit snugly against the side of the blades, and the under-cut side of the ring groove. Impulse blades are shrouded to prevent the steam from spilling over the ends. Reaction blading is made of phosphor-bronze, with the root ends slightly upset and a small hook or shoulder formed on one side as shown in Fig. 2. The grooves in the rotor and cylinder are of dovetail section, and have a small auxiliary groove of rectangular cross-section in the bottom. The steel packing pieces are beveled on the sides to fit snugly in the dovetail grooves and the shoulders formed on the lower ends of the blades project into the auxiliary grooves and hook under the packing pieces.

With the largest sizes of reaction blading, double wedges are used in one side of the blading groove, which are similar to those used for securing the impulse blades. The outer ends of the blades are tied together with comma lashing. The blades are punched with comma-shaped holes, Fig. 3, and a wire of the same section is threaded through these holes; after the blades are straightened and gaged, the part of the lashing wire that in section corresponds to the tail of the comma, is curled over, forming a rigid separator, or distance piece between the blades. For the longest reaction blades, 2 lashings are used, one at the middle of the blade and one near the outer end.

In the combination impulse and reaction turbines, nozzle chambers are independent castings, the root section of stationary guide blades between the first and second rows of impulse blades being attached to the nozzle chamber. There are 2 nozle chambers in each turbine, the primary, and the secondary, which comes into action only when the turbine is loaded above its normal or rated capacity.

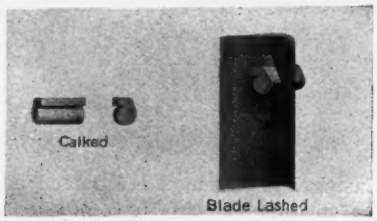


FIG. 3. WESTINGHOUSE COMMA LASHING

In the Westinghouse turbines, a bronze casting like the runner of a small centrifugal pump is pressed on the shaft, and rotates in an annular chamber surrounding the opening in the end of the turbine cylinder through which the shaft projects. Water is fed to this annular chamber, and under the action of centrifugal force, builds up a fluid wall between the bronze runner and the turbine casing, which is strong enough to resist a pressure of more than 30 lb. per square inch. The grooved hubs on the bronze runner constitute an ordinary labyrinth packing that may be temporarily sealed with water or low-pressure steam while the turbine is being started.

Figure 4 is a view of the governor, with the casing removed; it is driven from the main shaft through a worm gear. The ball levers and the links connecting these levers to the governor sleeve are all pivoted on hard chrome steel knife edges, which eliminate frictional disturbances; the main spring surrounds the spindle and bears directly on the governor sleeve. A small auxiliary spring, with a manually or electrically-operated tension gear for making small speed adjust-

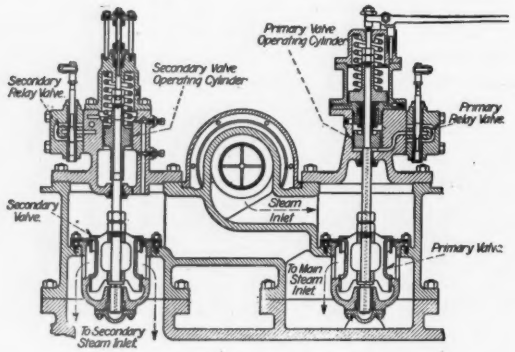


FIG. 5. VALVE GEAR WITH STEAM RELAY

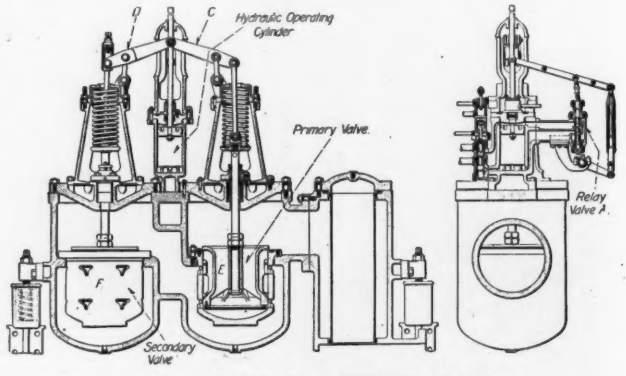


FIG. 6. VALVE GEAR WITH OIL RELAY

ments while running, is connected to the governor linkage, and is used in synchronizing alternators or in distributing the electrical load among them.

In the smaller turbines, the governor acts directly on the steam admission valves, opening first the primary valve, and then, if necessary, the secondary valve. In single-flow turbines the governor actuates 2 small valves controlling ports leading to steam relay cylinder which operate the admission valves. The little valve controlling the relay cylinder for the secondary valve has more lap than the other and consequently does not come into action until the primary valve has attained its maximum effective opening. Figure 5 shows the general design of this type of valve gear.

FIG. 4. TURBINE GOVERNOR

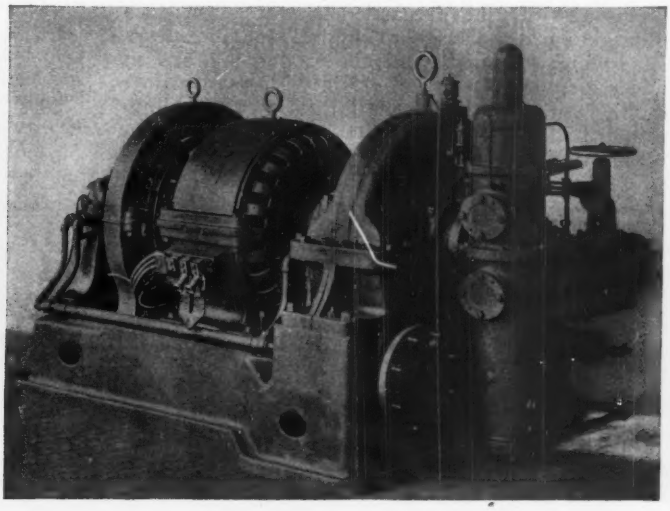


FIG. 1. ONE HUNDRED-KW. TURBO-GENRATOR SET

Governors for the larger turbines, particularly those of the combination impulse and reaction double, or semi-double-flow type, employ an oil-relay mechanism, illustrated in Fig. 6, for operating the steam valves. In these turbines the lubricating oil circulating pump, maintains a higher pressure than is required for the lubricating system. The governor controls a small relay valve A, which admits presure oil to, or exhausts it from the operating cylinder.

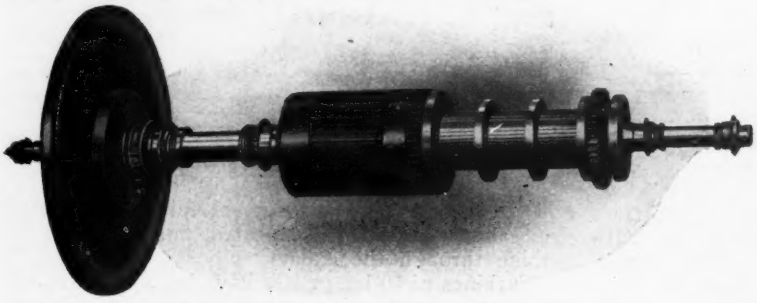


FIG. 3. ROTOR OF TURBO-GENERATOR SET

When oil is admitted to the operating cylinder raising the piston, the lever C lifts the primary valve E. The lever D moves simultaneously with C, but on account of the slotted connection with the stem of the secondary valve F, the latter does not begin to lift until the primary valve is raised to the point at which its effective opening ceases to be increased by further upward travel.

The operating valve A is connected not only to the governor, but also to a vibrator, which gives it a slight but continuous reciprocating motion, keeping ready to respond instantly to the smallest change in the position of the governor. In case of failure of the lubricating oil supply the relay will shut off the steam and stop the turbine.

Every Westinghouse turbine is fitted with a separate speed-limit governor, which, whenever the turbine attains the over-speed limit, trips an automatic stop valve, and shuts off the steam supply. When shutting the turbine down a pull on the governor linkage will speed up the turbine until the limit governor acts, insuring that the safety-stop mechanism is in condition to act.

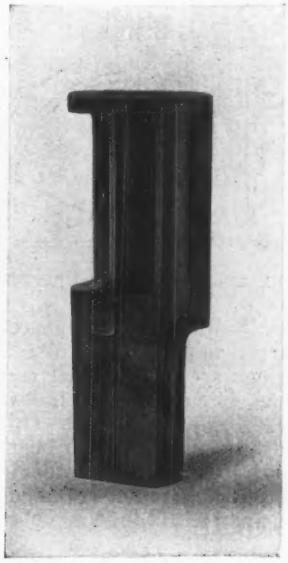


FIG. 2. THE BLADES

In turbines running at speeds of more than 3000 r.p.m. the spindle tends to rotate on its gravity axis instead of its mechanical axis; and to compensate for a possible small difference, the bearings are made up of several concentric tubes with slight clearance between them, the lubricating oil filling these clearances, forming an elastic cushion, and allowing the spindle to find its true center of rotation.

This nest of tubes is carried in a cast-iron sleeve resting on a pedestal, and having on the outside 4 steel blocks which extend beyond the casting and are machined to spherical surface which, with a corresponding spherical bore of the pedestal, forms a self-alining ball and socket bearing. Rolled-steel shims, of thickness in multiples of 0.005 in., back up the steel blocks and give final adjustment for centering the spindle.

In the larger and slower-running turbines, the self-alining bearings are made in halves and babbit-lined.

Continuous circulation of oil is maintained by a pump geared to the main shaft of the turbine, which keeps the turbine and generator bearings flooded with oil at a moderate pressure. From the bearings, the oil drains through a strainer into a collecting reservoir, whence it is pumped through a cooler, and back to the bearings.

When oil is taken from the oil-relay governing system, the comparatively small quantity of oil required for operating the valve mechanism passes to the relay cylinder, thence into the cooler, the remainder discharging directly into the cooler through a spring-loaded pressure-reducing valve, so that pressure in the main circulation is the same, whether the oil-relay governing system is employed or not.

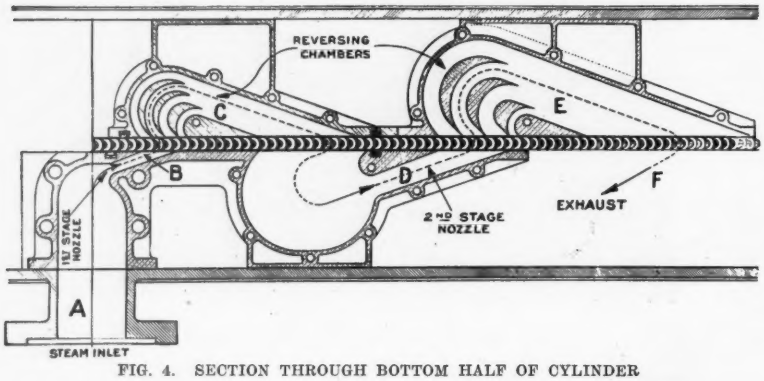


FIG. 4. SECTION THROUGH BOTTOM HALF OF CYLINDER

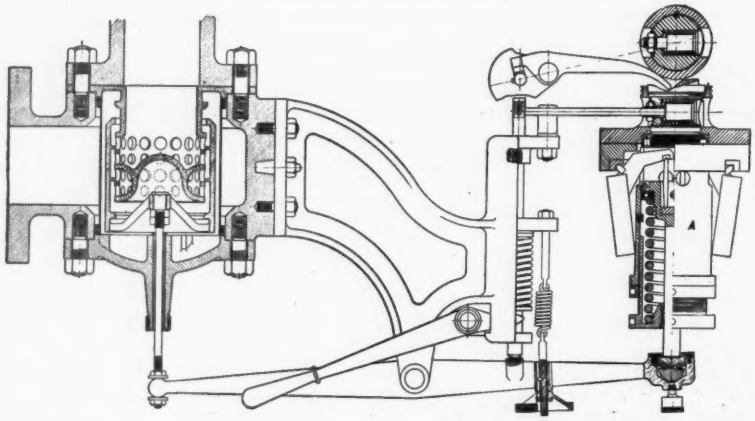


FIG. 5. GOVERNOR AND SAFETY STOP

WESTINGHOUSE TURBINES FOR SMALL POWERS

The Westinghouse Machine Co., East Pittsburgh, Pa.

IN Westinghouse turbines for small powers the moving wheel, or rotor, is a steel casting, with blades inserted in a groove cut in the periphery of the wheel, and held in place by double or triple rivets in each blade, according to size and speed. The cast-iron cylinder is split horizontally, a section through the bottom half of a turbine cylinder being shown diagrammatically in Fig. 4.

Steam enters the turbine at A, through a valve of the double seated poppet type; passing the first stage nozzles B, it impinges on the moving blades, giving up part of its energy, thence passes to the first reversing chamber C, where its direction is changed and it is made to pass again through the moving blades, giving up the balance of the energy imparted by the first stage nozzles. The steam then passes through the second stage nozzles D and the second stage reversing chamber E, where the cycle above described is repeated, finally leaving the turbine through the exhaust pipe F.

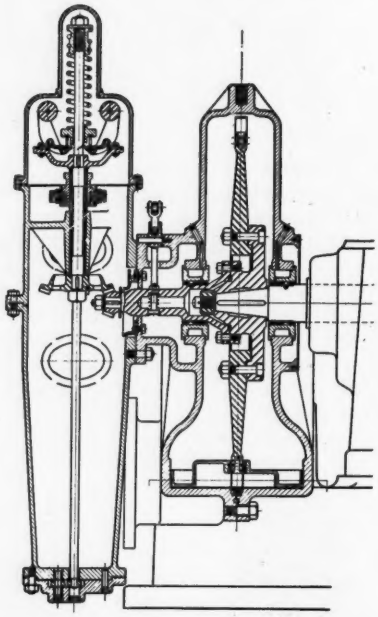


FIG. 6. SENSITIVE TYPE OF GOVERNOR

Turbines of 50 hp. or less have but one set of nozzles and one reversing chamber; all others have 2 stages. The nozzle blocks and reversing chambers are made of bronze and finished by hand to insure the minimum of friction losses due to steam passing over these surfaces.

Two general types of governor are employed. For turbines driving centrifugal pumps, fans and the like, where exceedingly sensitive regulation is not required, a shaft governor of the type shown in Fig. 5 is used. On the larger machines for electric drive, the general design illustrated in Fig. 6 is used, of flyball type, driven from the turbine shaft by bevel gears. With all turbines, an automatic safety stop is provided, which shuts off steam in case of overspeed.

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1913

Spite of the 13 on the end, the new year gives promise of being one of prosperity and progress. Business and employment for skilled labor are plenty, and the spirit of the country is cheerful.

There is no good reason for starting reforms with Jan. 1 more than at any other time, but there is no reason for delaying them, so the new year is a good time to start things right that have been wrong and to do things which have been done well, even better.

And so it's a good time to be joyous and progressive; and here's wishing full measure of cheer and advancement to all who read these lines,—and to everybody else.

RESOLVES AND RESULTS

Speaking of doing things better, there's a difference between making a plant run and making it run —well. And there's another step up to making it do its best.

The last named condition doesn't mean the most modern apparatus always, but getting out of what you have all there is in it of capacity and efficiency. Modern machinery is good if handled right and kept in condition. If allowed to get in bad shape it may not be able to show any better results than less perfect installations.

And so, to get the best out of a plant,—it's not a new statement, but needs new emphasis lest we forget, —calls for study and watchfulness and experimenting. There is no universal cure for all ills in power machinery any more than in human machinery, and an engine good for one place may be unwise for another.

Reading, without thinking and trying to apply the facts learned to our own problems is not study. Looking around without purpose or plan is not watchfulness. Trying something new without reason for it or knowing what result is desired is not experimenting.

Just keeping busy isn't working, it's only fussing. Activity with a definite purpose is what counts.

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NEWS NOTES

THE INTEREST held by Henry Hess in the Hess-Bright Mfg. Co., of Philadelphia, has been taken over by a German company and large additions will be made to the German works, although the controlling ownership will still remain in America.

PETER NEFF, who for many years has been with the Arctic Ice Machine Co., has opened an office as consulting engineer, especialy on refrigeration topics, in Canton, O.

MISS J. ARMINSON MACINTYRE, for over 10 yr. Manager of the Publicity Department of the C. W. Hunt Co., West New Brighton, New York, has resigned that position and it is understood that Miss MacIntyre will travel for a time.

Communications after Jan. 1 should be addressed care of National Arts Club, New York City.

ON THE EVENING of December 13 a dinner was given in honor of Dean W. F. M. Goss by local members of the American Society of Mechanical Engineers, members of the faculty of the College of Engineering and members of the Council of Administrations of the University of Illinois. The dinner was given in recognition of the election of Dean Goss to the presidency of the American Society of Mechanical Engineers.

THE ENGINEERING EXPERIMENT STATION of the University of Illinois has undertaken the study of the effect of certain boiler water on the strength and brittleness of steel in boiler plates.

THE YALE & TOWNE Manufacturing Co., 9 Murray St., New York, announces the following change:

R. T. Hodgkins, for several years manager of our chain block department, has resigned to accept a position with another company.

Chas. W. Beaver, who for many years has been connected with our chain block department, first as salesman and later as assistant manager of the department, and who, for the past 2 years, has acted as our special representative in Europe, has been appointed to the position made vacant by Mr. Hodgkins' resignation, and will assume the duties of his new office about February 1.

WILLIAM BROWN DICKSON, President of the International Steam Pump Co., was born in Pittsburgh, Pa., on Nov. 6, 1865. He was educated in the public schools of Pittsburgh.

Mr. Dickson commenced work at an early age and, in 1881, secured employment at the Homestead Steel Works which had just been built and placed in operation. After several years passed at manual labor in the mills, he was transferred to the office, acting at first in a clerical capacity and subsequently receiving rapid promotion through various grades up to that of assistant to president, and managing director of the Carnegie Steel Co. He became a junior partner in the Carnegie Steel Co., Limited, in 1899. On the formation of the United States Steel Corporation in 1901, he accompanied Mr. C. M. Schwab to New York as Assistant to the President of the United States Steel Corporation and later was elected a vice-president of that corporation, which position he held until May 1, 1911, when he resigned in order to retire from active business.

Mr. Dickson was elected President of the International Steam Pump Co., on Nov. 19, 1912. He succeeded the late Benjamin Guggenheim, who went down on the Titanic. Those who are familiar with Mr. Dickson's record in the steel industry do not hesitate to say that the International Steam Pump Co. made a wise selection.

A LARGE MILL is being built at Fort St. Joe, Fla. The estimated cost is between $150,000 and $200,000. The mill is to have a capacity of 75,000 ft. a day, and is expected to be in operation between May 1 and June 1.

AN APPROPRIATION of $80,000 will be asked of the Montana legislature this winter for the completion of the state's hydro-electric power plant at Race Track. The matter of the building of this plant was taken up by the state board of prison commissioners several years ago. Preliminary surveys were made, rights of way and water rights obtained, and then a crew of prisoners was put to work cutting a 5-mile canal out of the solid rock to deliver water into a reservoir just above the site selected for the generators. Another crew was put to work at the state's sawmill, getting out lumber for the flume through which the water will be delivered to the plant.

Engineers have passed upon the feasibility of the project, and declare it to be one of the best small sized developments in the west. Governor Edwin L. Norris, Attorney General A. J. Galen and the late Secretary of State A. N. Yoder were the originators of the proposition. Mr. Yoder's successor on the board, T. M. Swindlehurst, gives it as his opinion that the building of this plant is one of the most important affairs of the state government, and one that will redound to the financial interest of the state.

The total minimum development will be 1000 hp. Two hundred horsepower will be consumed at the state prison at Deer Lodge, at the Warm Springs insane asylum, and at the state tuberculosis hospital, leaving a surplus of 800 hp., which can be readily sold at $35 a horsepower a year. This would yield a revenue of $28,000, and in addition, the use of the power at the 3 state institutions would do much to reduce the maintenance expenses. Race Track lies midway between Deer Lodge and Warm Springs, and a transmission line 13 miles long would connect all 3 state institutions, as well as the town of Deer Lodge, where the power could be sold.

George J. Henry, a hydraulic and mechanical engineer of San Francisco, has made a report on the proposed installation, showing the plant can be constructed and equipped for $80,000, and that on the closest figuring it will yield at least 21 per cent on the money invested.

THE WEST PENN Traction & Water Power Co. has recently closed a contract for the complete electrification of the large mills of the Apollo Steel Co., at Apollo, Pa., and the erection and construction of the first motor installment, consisting of a 1500-hp. General Electric alternating-current motor, is now going forward. This marks a most important step in the development of a new field for electric power companies,— namely, the eletrification of steel mills. The Apollo Steel Co., will have no steam equipment of any sort. Its entire plant will be operated by electric power furnished by the West Penn Traction & Water Power Co., and includes the giant rolls which it has been generally believed until this time could only be operated by steam engines.

Work is to begin immediately on the erection of a new 500-ton mill in the Porto Rico field in Missouri. Electric power is to be used for the operation of the mill. Plans already have been made for the installation of motors throughout. Ore is found in a sheet formation and yields an average recovery of about 3 per cent. A number of concentrating plants have been erected on similar leases in the last few years in the Porto Rico field and all of them have made good.

Sparks From The Advertising Pages

The last few years have witnessed a remarkable improvement in the "tone" of business in the United States. In spite of the "muck raking" that has yielded so many sensational stories to the press, it is obvious that business is steadily becoming cleaner, more upright, more honest.

It is idle to question whether it is the head or the heart of business that is dictating closer adherence to the principle of "honesty the best policy." The important matter is that the principle is being more widely recognized and more consistently followed.

Advertising has responded to this impulse toward cleaner methods of business. Very naturally so, for advertising is a true mirror of business conditions and practices.

The movement for the elimination of fraudulent, dishonest and misleading advertisers, progresses briskly. Uncle Sam, through the post office department, keeps a watchful eye on violations of the laws bearing on fake propositions, and advertisers are getting together in an effort to suppress lying and misrepresentation in advertised offers. Only the other day, business men of Wichita, Kansas, secured the conviction and punishment of a piano sales promoter who had offered standard makes at ridiculously low prices but neglected to mention that they were second-hand.

The circle of fraudulent advertisers is gradually contracting and embraces today mostly the "fly-by-night" species of business men, for it requires but little intelligence to perceive that the man who intends to stay in business cannot afford to make misstatements. Retribution for the falsifying advertiser is sure and sometimes swift. Truth-telling is the only paying policy.

The efforts of advertisers to make advertising clean, are being ably supported by all first-class publications. Indeed, in many cases, the movement has gone beyond the mere exclusion of dishonesty, exaggeration and misstatement. Many publishers have placed some lines of advertising on their black list, not because the statements made in regard to them are untrue, but because (in the opinion of the publishers) the advertising of certain propositions does not conduce to the public welfare.

The rigid censorship of the advertising columns with a view to the exclusion of unreliable offers, has two advantages for the public. It saves their money and it saves their time.

The old vicious "principle," so-called, of buying and selling, was "caveat emptor"—let the buyer look out for himself. But the buyer, in the modern complexity and variety of commodities, is often in no position to protect himself in a purchase. It is here that the press can and does frequently help him by refusing to put before him offerings which do not give a fair return for his cash.

Then also, this conscientious attitude of the press toward advertising, is a big advantage to the buyer in saving him time and trouble. To respond to an advertisement and receive information showing that a commodity is not at all what the buyer wants, is not so serious as losing money in a straightaway purchase, but it is none the less a vexatious experience.

Readers of Practical Engineer can feel absolutely sure that its advertising pages present no offer that is not absolutely on the square, and that when they spend their time in the investigation of advertisers' claims, it is time well spent.

PRACTICAL ENGINEER CLASSIFIED ADVERTISEMENTS

Advertisements in this section are inserted under regular headings at the rates of 30 cents per line. About nine words make a line. No display type allowed, but the first three words may be set in capital letters. Minimum space sold, two lines.

Under classification, "Positions Wanted," advertisements not exceeding four lines will be inserted for subscribers once free of charge.

To insure proper classification, copy must reach this office 10 days preceding publication.

Positions Wanted

POSITION WANTED—By engineer of gas engines. Experienced in operating and repairing gasoline engines up to 100 horsepower. Age, 22 years. I. C. S. course. Exemplary habits. At present in charge of repairs and operation of 65 horsepower plant. Address Box 266, care of Practical Engineer, Chicago, Ill. 1-1-1

POSITION WANTED—BY ENERGETIC and progressive young man of 24, as assistant in medium size modern steam-electric plant. 3 years' experience with large Corliss engines. I. C. S. graduate and Chicago City License. Address Box 263, care of Practical Engineer, Chicago, Ill. 1-1-1

POSITION WANTED—AS CHIEF ENGINEER by man with over 15 years' experience as Chief of large Refrigerating and electrical plant. Thoroughly competent to handle plant and men. Strictly sober. Best References and License. Address Box 261, care of Practical Engineer, Chicago, Ill. 1-1-1

POSITION WANTED—AS MANAGER or superintendent of ice, light or water plant. Have technical education, and several years' experience. Can invest a small amount in plant. Address A. H. Conn., Hazlehurst, Miss. 1-1-1

POSITION WANTED—AS CHIEF ENGINEER in large ice and cold storage plant. Can handle either A. C. or D. C. machines, but prefer a position where there is no light plant in connection. Am a graduate from the No. 6 scoop. Three years in the manufacturing of artificial gas, both coal and oil gas. One year as engineer and electrician in small light and water plant. Will take some stock in small ice and light plant in good thriving little city in south. Will take no position on salary at less than $150.00 per month. Address J. F. Whitehurst, 1642 N. Halsted St., Chicago, Ill. 1-1-1

Wanted

WANTED—Man of wide acquaintance among engineers to solicit subscriptions for Practical Engineer in Pittsburgh, Pa. A good opportunity for the right man. tf.

WANTED—ALL STEAM USERS to have clean boilers without using compounds or chemicals in any form. Write "Otis," No. 317 Norfolk Ave., Buffalo, N. Y. tf.

WANTED EVERY ENGINEER to have our pamphlet for setting valves on Corliss Engines, simple and compound, with one or two eccentrics. Sent free. Lindstrom's Machine Works, 200 South Third St., Allentown, Pa. tf

IF YOU ARE a night engineer, spend a few hours each day taking subscriptions for Practical Engineer. You will be paid well. Write Subscription Dept. They will start you in at once. tf

Help Wanted

WANTED—An additional subscription solicitor wanted to cover towns in state of Washington. Excellent chance to earn extra money. Write to Subscription Department. tf

WANTED—MECHANICAL ENGINEER desires New England Agency for steam specialties, mill supplies, or large selling proposition exclusively. Fifteen years in general engineering, seven years as sales engineer. Has established office sales-force and trade connections. Will arrange an interview New York or Boston. Address M, Room 33, 164 Federal St., Boston. 1-1-1

For Sale

FOR SALE—AIR COMPRESSOR Rand Drill Company, Imperial type No. 11, 8x10 belt drive. Morrison Bros., Dubuque, Iowa. 1-1-1

FOR SALE—10x22 Corliss engine, in perfect condition, entirely overhauled, wheel 9 ft. by 14 inches, r.h. $375 f.o.b. New York. Duzets & Son, 40 Church St., New York.

FOR SALE—A 32 H. P. HORNSBY-AKROYD Oil Engine with starting device, in very good condition; also a 15-ton Challoner refrigerating machine, oil separator, double pipe ammonia condenser and high and low pressure gauges. These are also in good condition. For particulars inquire of the Rahr Br'g Co., Oshkosh, Wis. 1-1-6

Patents and Patent Attorneys

PATENTABLE IDEAS WANTED—Send for 3 free books. R. B. Owens, 28 Owens Bldg., Washington, D. C. tf

PATENT APPLICATIONS—prepared and prosecuted for $25. Send for booklet. Harry Patton, 330 McGill Bldg., Washington, D. C. tf

WE SELL PATENTS. Established ten years. To buy or having one to sell write Charles A. Scott Co., 1098 Granite Bldg., Rochester, N. Y. 8-1-6 e.o.i.

THE PATENTOME is interesting and instructive. A liberal education in patents and how to get them. Free on request. Established 1865. Anderson & Son, Patent Solicitors, 710 G. St., Washington, D. C. 1-1-2

PATENTS—C. L. Parker, Attorney-at-Law and Solicitor of Patents. Patents secured promptly and with special regard to the legal protection of the invention. Handbook for inventors sent upon request, 186 McGill Building, Washington, D. C. tf

PATENTS—H. W. T. Jenner, Patent Attorney and Mechanical Expert, 608 F St., Washington, D. C. Established, 1883. I make a free examination and report if a patent can be had and the exact cost. Send for full information. tf. e.o.i.

FIND OUT FOR YOURSELF what to invent and how to procure and sell a patent for the same. My book, "Inventor's Universal Educator," covers the matter from A to Z. 140 pages, elegantly bound. Also contains 600 mechanical movements and 50 perpetual motions. Price $1.00, postage free. Money returned if not more than satisfactory. F. G. Dieterich, 618 Ouray Bldg., Washington, D. C. 1-1-1

Educational and Instruction

ENGINEERS' POCKET MANUAL, 175 pages, edited by University of Tennessee will be mailed every subscriber sending in one new subscription to Practical Engineer. Gilt edges, bound in leather. tf

Miscellaneous

ENGINEERS—DO YOU WANT to utilize your exhaust steam for heating or drying purposes without back pressure on your engine? If so, address Monash-Younker Co., 1413 W. Jackson Blvd., Chicago, Ill. tf

MAKE MONEY on the side. Here's your chance to work out some money for yourself. Get subscriptions for Practical Engineer. It pays well. Just drop a line to the Subscription Dept. They will tell you how. tf